Residential Title Page Place Holder

1 EXECUTIVE SUMMARY

This section provides an overview of the study, from the purpose and objectives to the findings and recommendations.

1.1 PURPOSE AND OBJECTIVES

The overall purpose of this study was to determine baseline construc tion practices of newly constructed homes following the implementation of the RBES code, and to assess the efficiency of lighting and common appliances being installed in these homes. Although not an exhaustive impact analysis of the efficiency program impacts, this study also highlights the effects of the the utility DSM programs of the late 1990's and the ongoing efficiency programs currently implemented by Efficiency Vermont efficiency activities, as appropriate.

This study was accomplished through the following four strategies:

1. Determine current construction practices based on nearly160 onsite surveys of newly constructed houses.
2. Assess the level of code compliance based on the onsite survey data and investigate the reasons for noncompliance.
3. Measure the saturation levels of efficient lighting and appliances.
4. Compare current construction practices to construction practices prior to the RBES code.

1.2 SAMPLE DESIGN

The general strategy for the sample design was a simple random sample of all newly constructed one and two family homes in the state to provide a basis for statistically valid estimation of statewide code compliance. The sample was designed to provide a total of 160 visits, and 158 site visits were completed.

A nested sampling approach was employed. First, potential participants were asked to respond to the telephone survey, and then solicited for the on site survey after completion of the phone questionnaire. Seventy-six of the 158 survey participants were solicited through this nested sampling approach, and the rest were contacted directly from the remaining names in the sample frame, i.e., those were who could not be reached initially or did not want to participate in the telephone survey.

1.3 BUILDING DATA ANALYSIS APPROACH

The analysis is based on site surveys of 158 homes for thermal shell characteristics and lighting, and 159 homes for appliances. The site visit consisted of collecting detailed information on all aspects of the thermal shell, equipment and appliances, and performing a blower door test.

There are three verification methods for RBES code compliance, i.e., the VTCheck software, meeting the Home Energy Rating standard and the prescriptive approach. For most homes in the study, compliance was determined by the VTCheck methodology. Compliance for the nineteen homes that went through the Vermont Star Homes program and received energy ratings was assessed by the Home Energy Rating standard. Homes that failed to meet compliance by either of these methods also failed the prescriptive path.

For the 139 homes where the blower door test was done as part of the site visit, the test and calculation of the natural air changes per hour were designed to be consistent with ASHRAE standards for comparison with the ASHRAE ventilation standard. In nineteen homes, the builder participated in the Vermont Star Homes and the home received in energy rating. For these home, the blower door test was conducted by program staff and the methodology for calculating the natural air changes per hour was slightly different.

1.4 FINDINGS

The results of this study show some impressive gains in some common building practices. In comparison to the 1995 baseline study, heating system efficiencies have improved, the saturation of high efficiency windows has increased from about 70% to 80% for low E and from 38% to 50% for gas filled, and the most inefficient DHW systems (tankless coils) have virtually disappeared from new homes, down from almost 30% in 1995 to 3% in 2002. The potential impact of these efficiency gains, however, is offset by some other significant trends. The pressure to build larger homes appears to be continuing, and the new homes in this sample, particularly the large homes, tend to have a much larger proportion of glazing than found in the previous study. Excessive oversizing of heating equipment is still a common practice.

While most homes are built at a midlevel of efficiency or higher, there are still a few homes being constructed with little regard to basic efficiency standards. About a quarter of the sample failed to come within 30% of the RBES compliance standard. In one-third of these homes, the high window glazing percentage was a contributing factor to the failure to meet code. Owner-built and manufactured homes account for more than half of this bottom stratum.

1.4.1 House Size

The new homes in the survey were large, averaging over 2,500 square feet with a 95% confidence interval of 2,284 to 2,545 square feet. The average home had over 800 square feet per occupant. A contributing factor to the considerable size of the living area was the prevalence of finished area in the basement.

The large, and sometimes excessive, house sizes have two major ramifications. First, and most obvious, is that larger homes use more energy, and this additional energy usage cannot be entirely offset by increasing the efficiency of the homes. The second implication is that the combination of large homes and few occupants makes it easier for these homes to meet the ASHRAE ventilation standards.

1.4.2 Code Compliance

A majority of the homes (58% +/- 8%) passed the RBES code using the VTCheck software methodology or energy rating data where available. This result represents a substantial improvement over the 1995 baseline study, in which 35 to 40% of the homes were estimated to pass the RBES standards. The major reasons for non-compliance with the code were the absence of foundation insulation and the high ratio of glazing-to-wall-area.

Although 58% passed, a low proportion (18%) had completed RBES certification forms in their homes.[1] Four of the 28 homes with RBES certificates displayed actually failed the VTCheck criteria by a wide margin.

The relatively high percentage of homes passing the standard must be balanced against the reality of the standard building practices. Some homes that passed through the VTCheck methodology did not meet some basic efficiency standards, such as insulation levels of R-38 or higher in attic flats or R-30 in attic slopes. Also, the code does not cover some aspects of energy efficiency, such as air infiltration standards and heating system sizing.

1.4.3 Manufactured Housing

Manufactured housing accounts for a substantial part of the market, at least 17% +/- 6% at the 95% confidence level. It is possible that this proportion is understated. Although this component of the housing stock is commonly produced to meet minimum code requirements when it leaves the factory, there is evidence to suggest that the thermal efficiency of these homes as installed on site is lower than site built homes.

[1] It is possible that the RBES certification was submitted to the Vermont Department of Public Service or the town clerk for some homes, but certification through these mechanisms has been quite low.

1.4.4 Thermal Shell and Ventilation

Insulation and glazing characteristics were similar to the 1995 baseline study with about 65% of the homes (90% for walls) meeting or exceeding the minimum prescriptive RBES standard. The one exception was a significant increase in the number of homes with foundation insulation from less than one half of the homes in 1995 with R-10 or more, to almost two-thirds of the homes meeting the minimum prescriptive RBES standard of R-10 in the current study. Other types of basement and foundation components, such as slabs, exposed floors and floors over unconditioned space, were underinsulated in most of the homes with these components.

Efficiency programs appear to be a major driver in promoting the mechanical ventilation in new homes. Whole house ventilation is required to meet the Vermont Star Home designation, and exhaust fans with timers are frequently recommended as a cost effective way to meet this standard. Participants in the utility or Vermont Star Homes programs were much more likely to install mechanical ventilation, including exhaust fans on timers (70% of homes as compared to 15% of the homes of nonparticipants).

Homes were tightly built, with two-thirds of the sample homes having a natural air changes per hour rate of .31 or less. Although the homes are tight, they generally meet the ASHRAE Standard 62 guidelines for air flow at the current occupancy levels.[2]

1.4.5 Heating and DHW Systems

Oil was the predominant fuel for both space and water heating, and the saturation of low efficiency tankless coil water heating systems dropped precipitously from almost 30% in the 1995 study to 3% in the current one. A large majority of the heating plants were in the mid to upper range of efficiencies. Most homes with boilers also had integrated water heating. As shown in the 1995 baseline study, heating systems were consistently oversized to an excessive degree. The median oversizing was 81%, approaching twice as much heating output as required by the load.

1.4.6 Lighting and Appliances

The average number of fixtures per home increased markedly from the 1995 study, from 25 to 34. The penetration of CFL lighting among participants of the statewide or utility efficiency programs is high, in terms of the percentage of homes using this technology (80%), the number of CFL fixtures installed per home (50% of homes with four or more) and the incidence of installation in high use locations. This result indicates that the rebates for CFL fixtures and

[2] Standard 62 requires 15 cfm per person. Consequently, the level of occupancy of the house has an impact on the air flow requirements.

technical assistance provided by the efficiency programs have been effective at promoting these products.

Among survey respondents who did not participant in any efficiency programs, the penetration of CLF fixtures was much lower in all respects, leading to the conclusion that CFL fixtures have still not achieved acceptance in the general market.

The penetration of Energy Star appliances was reasonably high, with 47% of clothes washers, 36% of dishwashers and 27% of refrigerators meeting the Energy Star criteria at the time of purchase. Program impact on appliance purchase was mixed, possibly reflecting a lesser degree of promotion of Energy Star appliances through the program prior to 2001. Central air conditioning was found in 6% of homes, the same saturation rate as hot tubs.

1.4.7 Comparison of On Site and Telephone Responses

By comparing the overlapping group of respondents who participated in both the on site and the telephone surveys, we were able to assess the comparability of the homes reflected in the two studies and evaluate the telephone responses in a few key areas. The two surveys appear to be quite similar in regard to house size, RBES compliance and participation in efficiency programs. This comparison also uncovered a number of areas where homeowner telephone responses did not correspond well with the results of the on site survey. The largest discrepancy related to electric water heating. While the on site survey concluded that 8% of the homes had an electric water heater, the results of the telephone survey indicated 25%. Comparison of the overlapping group showed that the homeowners' responses were largely unreliable for this piece of information, with thirteen out of seventeen incorrect responses.

For a number of other house characteristics, the discrepancies between the telephone and on site survey responses were in the range of 15 to 30%. On average, the telephone responses underestimated house size by about 15 to 20%, with owners of smaller homes (under 2,300 square feet) providing reasonably accurate responses and owners of large homes (over 2,300) consistently underestimating the size of their homes. There tended to be some confusion among homeowners regarding the difference between primary and secondary heating systems and between natural gas and propane. Homeowners on average were more likely to state that they heat with a forced air system, although the auditor identified a hydronic system. When the responses from the overlapping group were corrected by the confirmed data from the on site visit, the distribution of house sizes, fuel types and heating system types for this subset corresponded well with the results of the on site survey as a whole.

As is consistent with the finding of similar studies in other states, many homeowners tended to identify their appliances as "energy efficient" although a smaller percentage purchased Energy Star models. While two-third to three-quarters of homeowners identified their appliances as "energy efficient," Energy Star appliances were verified in about one-third to one half of the homes.

The last data point compared was manufactured housing. Although both the telephone and on site survey results indicate that about 17% of the new homes were manufactured housing, it is possible that both surveys underestimated the penetration of this type of construction. In the overlapping group, homeowners underrepresented their homes as manufactured homes by about 30% on average. For the on site survey, “manufactured home” was not a specific data point on the survey form, and these homes were identified from auditors’ notes and builder information, leaving the possibility that some manufactured homes could have been missed. Consequently, the 17% should be seen as a lower boundary of the penetration manufactured homes.

1.5 RECOMMENDATIONS

This section is divided into three parts: recommendations for future efficiency efforts in the residential new construction market, policy implications, and suggestions for the next round of evaluation efforts in this market.

1.5.1 Efficiency Potential

This study highlights a number of areas for potential efficiency improvements. The fact that 42% of the homes failed to meet the RBES standard, and about 30% failed by a substantial margin (more than 10%), emphasizes the importance of continuing to offer code support. Approximately half of the homes failing to meet the RBES standard by more than 10% were either owner-built or manufactured housing, indicating that efficiency efforts need to be designed to reach these groups. Efforts to improve the efficiency of manufactured housing should have a two pronged approach, with one set of initiative to encourage manufacturers to produce homes above the minimum standard and the second to promote efficiency building practices among the owners and builders who install the homes on site.

There are a few specific components of common construction practice that could be improved. With 73% of the homes built with 16" on center 2 x 6 wall construction, continuing program efforts to promote the use of 24" stud spacing in 2 x 6 walls, engineered corners and R-21 fiberglass would be warranted. This study also points to the need to continue to stress the importance of complete foundation insulation, including slab edges.

The excessive heating system oversizing shown to be common among the surveyed homes also presents opportunities for efficiency improvements. While recommended practice by ASHRAE standards is to oversize heating equipment by 25%, the median oversizing among the surveyed homes was 81%. Efficiency efforts would have to be targeted to heating contractors and attempt to address the causes for the current practice.

Efficiency programs to date have been shown to be making solid progress in promoting efficient lighting and whole house ventilation using exhaust fans. Their track record on other energy star appliances appears to be more mixed. The next challenge is to influence the purchase and installation of these efficient products on a wider scale.

A final issue for consideration in program implementation is the few homes (4) in which the homeowners believed the homes had received energy ratings through the program, but in actuality had not. Program implementers need to be aware of the balance between maintaining good relations with contractors and ensuring the integrity of their program.

1.5.2 Policy Implications

The trend toward larger homes with a higher percentage of glazing is likely to increase overall energy use to a far greater degree than can be offset by efficiency improvements. This pattern overshadows the overall goal of reducing energy usage, and cannot be effectively addressed through efficiency programs. While specific regulations to restrict house size are not likely to be feasible or desirable at this time, this trend should be considered in the context of state regulation and policies. One interesting finding of the survey was that Act 250 homes tended to be smaller on average than homes that were not subject to Act 250, although Act 250 does not have any specific size regulations. It is also entirely possible that a downturn in the economy will have an impact on the new construction market and the size and characteristics of new homes.

This study also points to a few area for potential code enhancements. While a majority of homes complied with the RBES code, there were still 42% that did not, and 30% that failed by a substantial margin. While these results may be considered to be reasonably good for a state with no code enforcement, they also indicate the need for continuing education and consideration of potential enforcement strategies. Program efforts to assist builders with RBES compliance may be providing critical services to this market segment. However, attempting to combine the efficiency program with enforcement may lead to deteriorating relationships with contractors. Since program success is highly dependent on developing and maintaining strong and positive relationships in the building community, coupling efficiency program efforts with enforcement strategies should be avoided.

Another result of this study indicates that the VTCheck software or prescriptive standards for insulation and heating equipment do not directly address some of the current lapses in building practices. Currently, the RBES code does not cover some relevant areas associated with the installation of insulation or heating system sizing. Also, the VTCheck software incorporates trade offs that allow homes to pass with substandard attic insulation. One approach would be to replace the VTCheck software with the prescriptive and performance-based standards. This approach would prevent homes from meeting the code standards with substandard insulation and be easier to administer, although fewer homes in the current study would have passed using this method.

This study indicates that it should be possible to raise the minimum AFUE requirements for furnaces and boilers, and to increase the windows requirements to a minimum requirement of low E and argon. Since integrated DHW tanks have become the rule, an increase in the required efficiency of DHW could move along the elimination of the low efficiency tankless coils.

Vermont could also consider taking a similar approach to Massachusetts and strengthening the other code requirements, such as maximum sizes for heating equipment, improved installation standards for insulation and a minimum standard for DHW efficiencies above the federal minimum code requirement. If these elements are added to the RBES code, careful consideration should be given to tracking compliance and other enforcement strategies.

1.5.3 Recommendations for Future Evaluation Efforts

The approach of investigating the market from various perspectives, as proposed in the 1995 baseline study, was used to good advantage in the current round of evaluation activities. The combination of the telephone and builder surveys conducted by Xenergy and the on site survey results presented in this document yielded a more complex picture of the market place, and this approach should be employed again for the next round.

The primary area for potential adjustments may be in the objectives and implementation of the on site surveys. In this study, a major goal of the on site surveys was to determine RBES compliance by use of the VTCheck software. This approach required substantial time and effort in collecting the data for this task alone, leaving little possibility of investigating other issues.

The comparison of the telephone survey responses to the on site verification may also be useful for refining the homeowner telephone survey. This comparison has highlighted specific areas where the homeowner telephone responses were more or less reliable, and can be used to focus the next telephone survey on the areas most likely to yield reliable results.

1.5.3.1 Approach to On Sites

We recommend revisiting the overall strategy for the next on site survey. Measuring and documenting the areas and characteristics of the attic, walls, windows and other building components for determining compliance through the VTCheck software comprised a very large and time-consuming part of the site visits. This decision to collect this detailed information limited the possibilities of investigating other issues.

Input from field staff and other sources point to areas beyond insulation levels where further investigation is warranted. These include point sources of indoor air pollutants such as garages and unvented appliances, DHW equipment and configuration, duct balancing and sealing, lighting levels and combustion safety.

In the next round, one approach would be to record only the insulation levels and quality of installation, but not measure the areas. This single change would tremendously reduce the amount of time spent on this component of the site visits and open up the possibility of collecting data to evaluate lighting levels, indoor pollutants, wall construction details, etc. The insulation levels could be checked against the RBES prescriptive requirements to assess compliance levels, for homes without energy ratings.

1.5.3.2 Questions for the Next Round

This study has illuminated some areas of building construction that should be further investigated in the next round. For the next study, we should consider adding the following questions.[3]

What is the actual penetration of manufactured homes among new homes?
Are manufactured homes less efficient than site built homes? If so, where is the potential for efficiency improvements?
Are homes overlit?
Is indoor air quality a problem in new homes?
Are there common issues with combustion safety?
Are heating and DHW systems correctly (and efficiently) configured and installed?
Are there common practices in the installation of insulation that effectively reduce the R-value?
What are common wall construction practices?
Are ducts properly balanced and sealed in homes with furnaces?
Are central A/C units properly sized?

Some of these issues were identified in the 1995 baseline study also, but as discussed above, the focus on measuring and recording areas for each building component limited our ability to address these issues.

[3] Many of these issues were highlighted by the subcontractors who performed the site visits. Their comments are included as Appendix 2.

2 INTRODUCTION AND OVERVIEW

From July 1, 1997 to July 1, 1998,Vermont phased in the implementation of a residential energy conservation code (RBES). The RBES code affords builders and architects design flexibility by allowing trade-offs between different building components, and between the building envelope and heating equipment efficiencies. The code was set at a level of energy efficiency significantly higher than the baseline practices established by the 1995 study of residential new homes. This study was designed to assess current baseline construction practices and compare them to the RBES code requirements. It was also designed to determine the saturation of high efficiency appliances and equipment.

Another factor impacting the energy efficiency of new homes in Vermont is the efficiency programs operated in the state over the last decade, starting with the utility programs in the early 1990's and continuing with the statewide programs implemented by Efficiency Vermont since 2000. In addition to programs specifically targeted at residential new construction, other programs designed to affect the appliance and lighting markets may also have an impact on new homes.

This report presents the baseline construction practices in new, single family homes in Vermont and compliance levels with the RBES code. Beyond the building envelope and heating systems, this study also assesses the saturation of energy efficient lighting and appliances in these new homes. The study was conducted by West Hill Energy and Computing, Inc. on behalf of the Vermont Department of Public Service with assistance from Xenergy, who provided assistance with developing the sampling plan and soliciting participants for the on site study.

The results of the study show improvement in home construction with respect to energy efficiency and code compliance as compared to the previous study in 1995.

2.1 PURPOSE AND OBJECTIVES

The overall purpose of this study was to determine baseline construction practices of newly constructed homes following the implementation of the RBES code, and to assess the efficiency of lighting and common appliances being installed in these homes. Although this study was not intended to be an exhaustive impact analysis of the efficiency program impacts on construction decisions and appliance purchases, some aspects of home building and appliance purchases are likely to be affected by the utility DSM programs of the late 1990's and the ongoing efficiency programs currently implemented by Efficiency Vermont, and this study will highlight the effects of these efficiency activities, as appropriate.

This study was accomplished through the following four strategies:

1. Determine current construction practices based on nearly 160 onsite surveys of newly constructed houses.
2. Assess the level of code compliance based on the onsite survey data and investigate the reasons for noncompliance.
3. Measure the saturation levels of efficient lighting and appliances.
4. Compare current construction practices to construction practices prior to the RBES code.

2.2 STUDY COMPONENTS

Three sources of data and information were employed to fulfill this study's objectives. The primary source of data came from the detailed, on-site reviews of the construction characteristics of 158 new homes in Vermont. This process included compiling detailed building characteristics data from an on site survey of each house in our sample. Two other sources were used for comparison and context: these were the study of baseline construction practices from site visits conducted in 1995 (prior to the RBES code) and Xenergy's recent telephone surveys of owners and builders of new homes in Vermont. Seventy-six of the 158 on site participants were recruited from these phone survey participants. A by-product of the nested sampling approach was the ability to compare the responses from the telephone surveys to the verified, on site data for a few key data points.

2.3 STUDY APPROACH

The details of our approach are discussed in subsequent sections of this report. Here we provide an overview of the approach.

The construction data collected via the onsite surveys provided the key inputs to several analyses. First, the data allowed us to document current construction practices for a numerous characteristics related to energy efficiency including window area, window type, envelope insulation levels, floor area, natural infiltration rates, etc. Second, the data were used to determine whether each home surveyed actually met the efficiency requirements of the new code. Based on these data, we were able to determine if each home complied with the code and the overall compliance level. Third, these data allowed us to explore what factors were responsible for noncompliance in homes that did not comply. The onsite survey data also permitted us to analyze specific issues related to common building practices. Two key issues of interest were the sizing of heating equipment and the saturation and efficiency levels of manufactured housing. Finally, we were able to establish the saturation of efficient appliances and lighting in these new homes.

Comparison of the results of the new on site survey to the previous baseline survey of homes built in 1993 and 1994 provides a general sense of the movement of the market over the past seven years, keeping in mind that the two studies were not designed to be longitudinal. Xenergy's telephone surveys of homeowners and builders provides context to the on site surveys, and illuminates areas of potential discrepancies to be resolved in further studies.

Finally, a by-product of the overlapping samples was the opportunity to compare phone responses to documented, on-site data for about half of the 158 survey participants. This comparison allowed us to verify homeowners' responses to a few key questions and to investigate the possibility of significant variations between the telephone and on site samples.

2.4 Report Contents

This report presents study findings at three different levels of detail. Section 1, the Executive Summary, briefly discusses the approach and highlights the key findings and recommendations. Sections 2 through 10 present more comprehensive information on how the study was conducted and highlights the findings on topics that were identified as being of primary interest. The appendixes are included to provide more detailed information about specific findings from the on site surveys.

Section 3 describes the steps taken to design a sample and the data collection process. Section 4 describes how we analyzed the current practice construction data to characterize current construction practices and assess code compliance.

Section 5 covers the findings on general house characteristics, including house size, participation in efficiency programs, construction types, owner-built and manufactured homes, and municipal water and sewer hook ups. Section 6 contains the results on RBES code compliance and construction practices related to ventilation and thermal shell characteristics. In Section 7, equipment and fuel choices for space heating and water heating are documented. Lighting and appliance efficiency and fuel choice is discussed in Section 8, and the comparison of responses between the telephone and on site surveys for the 76 homeowners who participated in both studies is explored in Section 9. Findings and recommendations can be found in Section 10.

3 CURRENT BUILDING PRACTICES DATA COLLECTION

This section discusses the sample design approach implemented to collect the on site data. It also discusses the data collection process.

3.1 SAMPLE DESIGN

Data collection to characterize building practices under the new code consisted of site inspections at newly built single- and two-family homes. A random sample of homes was selected to provide a basis for statistically valid estimation of statewide code compliance and baseline construction practices.

The general strategy for the sample design was a simple random sample of all new homes in the state, due to concerns about finding enough willing homeowners to obtain the 200 telephone surveys and 160 site visits. The sample was designed to provide a total of 160 visits, and 158 site visits were completed.

3.1.1 Details of the Sample Implementation

The sample frame was developed by comparing the 2000 and 2001 grand lists for each town in the state. For most of the 252 towns in Vermont, the grand lists were obtained from the Vermont Department of Property Valuation. Fourteen towns were excluded from the sample because the grand lists were not readily accessible and the level of new construction was low. For twenty-seven towns, the list of new homes was obtained directly from the town clerk.

A nested sampling approach was employed. First, potential participants were asked to respond to the telephone survey, and then solicited for the on site survey after completion of the phone questionnaire. The 200 phone surveys were completed before a sufficient number of on site participants were identified. Seventy-six of the 158 participants were identified in this manner. For these 76 respondents, it was possible to compare phone survey responses to on site data.

To reach the survey quota, additional participants were solicited from the remainder of the sample frame. A total of 232 homeowners agreed to the on site during the initial solicitation, resulting in the completion of 158 site visits.

3.2 DATA COLLECTION

We conducted site visits to the selected homes between February and August 2002. The field work was conducted by seven subcontractors, covering different sections of the state. Visits were performed by prior appointment only. Most visits occurred during normal working hours, but some were also performed during evenings and on Saturdays to achieve a sufficient participation sample size for the study's requirements and to avoid possible bias related to restricting the study to homeowners who are available during regular business hours.

Building components were checked through visual inspection and measurement. Several procedures were used to collect the data for each home: attics were accessed (if possible) and thoroughly inspected; walls were visually inspected; windows were checked for the presence of low emissivity (low-e) coatings; equipment nameplate data were recorded; blower doors were operated to identify building air exchange rates (Minneapolis Blower Door); and ducts were visually inspected. Homeowners were questioned about house components that could not be ascertained through visual inspection, as well as heating fuel usage, and use of ventilation systems and other general house information. If available, the auditors also used plans and the RBES certificate to ascertain the required information. In addition to data collection to assess code compliance, lighting and appliance data were gathered.

A premium was paid to each homeowner as a way of thanking them for their time and participation. A written report will be prepared and mailed to homeowners showing how their home compared to the average survey results.

A data collection form was used to enter the onsite data (see Appendix 1). On average, about 560 data points per home were collected. All the survey data collected onsite then were entered into a database and prepared for analysis. Table 3-1 summarizes the categories of data collected.

The detailed data collected for the envelope segments and heating system was used to assess code compliance based on the U-value/area methodology that is utilized by the VTCheck software.

Table 3-1
Summary of Data Collected for Each House

Data Category	Types of Data Collected
General Information	• Owner name, address • Completion/occupancy dates • Builder information • Act 250 • Private/public water and sewage • Use of whole house ventilation system
General Building Description	• Home type • Volume and floor area • Number of floors and bedrooms • Basement type • Orientation and footprint
Energy Code Compliance Information	• Familiarity with RBES code • RBES certificate displayed
VT*check* Compliance Information	• Areas/perimeters for multiple sections of ceilings,

Data Category	Types of Data Collected
	walls, basements, and floor and multiple doors, windows, and skylights • Insulation R-values for all components and sections • Heating and cooling equipment type and efficiencies • Calculated and required UA
Detailed Building Characteristics	• Details on each building envelope component • Areas/perimeters, orientation, location • Insulation R-values • Framing spacing • Window and skylight areas, orientation, frame type, glazing type, U-value • Door characteristics • Heating/cooling system type, heating fuel, capacity, efficiency, make, controls, zones, thermostat type, venting • Fans and ventilation
Water Heater Characteristics	• Fuel type, efficiency, size
Air Infiltration/Ventilation Characteristics	• Blower door measured air infiltration rate
Detailed Appliance and Lighting Characteristics	• Refrigerators, room air conditioners, dishwashers, clothes washers • Manufacturer, vintage • Fuel type for clothes dryers and cooking stoves • Number of ceiling fans • Lighting fixture type and location, lamp type, control type

4 BUILDING DATA ANALYSIS APPROACH

This section describes the approaches used to analyze the building data compiled for this study. It explains the collection of data to assess the on site current construction practices, the code compliance analysis approach, the method for calculating the natural air changes per hour and the process used to verify the data entry.

4.1 CURRENT CONSTRUCTION PRACTICE

The analysis is based on site surveys of 158 homes for thermal shell characteristics and lighting, and 159 homes for appliances. Of these 159 homes, 139 received complete site visits and the auditors collected partial data on the remaining 20, on the understanding that the homes had received energy ratings through the Vermont Star Homes program, and the thermal shell characteristics could be obtained from the program data files.[1] The data entered into the VTCheck analysis were built up from the detailed data collected on site for each building component and piece of equipment.

We analyzed these data by calculating the mean, median values and confidence intervals where appropriate for the quantitative building characteristics. For categorical data, we calculated the percent of houses that fell into different categories. In some cases, we documented the distribution of the values observed in the on site surveys.

4.2 CODE COMPLIANCE

There are three verification methods for RBES code compliance, i.e., prescriptive approach, the VTCheck software, and the performance standard based on the Home Energy Rating System (HERS). In general, the prescriptive path is the most restrictive standard. VTCheck allows a wider range of trade offs between equipment efficiency and thermal components, and is therefore easier to pass than the prescriptive standard. The Home Energy Rating is performance-based and takes into account numerous house characteristics, such a solar gain, that are not included in either the prescriptive packages or the VTCheck software. Homes that do not pass either the prescriptive or VTCheck methods may still pass by the performance standard; however, the results of the home energy rating must be documented as part of the compliance process.

For most homes in the study, compliance was determined by the VTCheck methodology. For the nineteen homes that received HERS ratings, the performance standard was applied based on the results of the energy rating. A review of the homes that failed to meet compliance by either of these two methods showed that these houses also failed the prescriptive path.

[1] In one case, the home did not actually receive the energy rating and the auditor could not reschedule. Consequently, only partial information covering lighting and appliances is available for this home. In another home, the lighting had not been installed at the time of the site visit.

We determined basic code compliance by running a simulation of VTCcheck software for each building based on the observed building characteristics collected on site. Using the VTCheck methodology, we calculated the maximum thermal transmittance (UA) allowed by the code and the UA calculated for the building as built ("Your Home" UA). The compliance software adjusted the allowable UA based on the efficiency of the heating equipment, with more efficient heating systems allowing higher building UAs. If the calculated UA was equal to or less than the maximum allowable value, we recorded in the database that the building complied with the code. These data, in combination with the energy rating results obtained from the Vermont Star Homes participants, allowed us to determine the proportion of houses that met the code and to document the distribution of the house UAs relative to the required level.

4.3 Blower Door Analysis

A blower door test was conducted as part of the site visit whenever possible. A single point pressurization and depressurization test was performed at 50Pa to determine CFM50. The average of these two values was used to determine the leakage area. This data point was then used to calculate the average natural air changes during the months of September through May. The methodology used is described in the 2001 ASHRAE fundamentals as the LBL model. It adjusts for building height, temperature difference and wind speed. An average temperature difference of 30° F and an average wind speed of 5 mph were used in the calculation. There are a total of 156 data points in the sample. Of these, 137 were collected on site using the methodology discussed above.

The blower door tests on the remaining19 homes were done by Energy Rated Homes of Vermont in conjunction with ratings for the Vermont Star Homes program. For these homes, the natural air changes per hour were obtained from the program data and were based on a single depressurization test. The calculations were done according to the methodology used by the program field staff.

4.4 Data Verification

All major data points were checked for valid entries and cross-referenced with other related data points. The data entry for thirty-two (20%) randomly selected surveys was checked against the hard copy, showing an error rate of less than 1%. A few basic data points were checked against the telephone survey responses to look for patterns of errors in data collection, but this process did not reveal any systematic problems.

5 GENERAL HOUSE CHARACTERISTICS

This section presents the findings on general house characteristics, including regional distribution, house size, program participation, construction types, and municipal water and sewage hook ups.

5.1 REGIONAL DISTRIBUTION

Homes were surveyed in thirteen of the fourteen counties in Vermont. Comparison to the estimated new homes for 2000 indicates that the geographical distribution may be favoring the northwest. However, further review indicates that any variations in geographical distribution do not appear to have any significant effect on the results of the study.

Table 5.1: Regional Distribution

Regions	On Site Survey		Telephone Survey	Estimated New Homes 2000[1]
	N	%	%	
N	158		200	2,196
Northwest	103	65%	61%	48%
Northeast	9	6%	8%	12%
Southwest/South Central	22	15%	18%	22%
Southeast	24	14%	14%	18%

Although the sample was not specifically designed for comparisons between geographic regions, the data was reviewed to identify substantial variations among regions, to the degree possible considering the small sample sizes. Table 5.2 compares house size, compliance with the RBES code, the penetration of modular homes and the percent of glazing as a proportion of the total wall area across the four regions. House size and percent glazing were chosen as indicators due to the overall trend toward larger homes with more glazing. These characteristics may also be indicators of higher end homes. RBES compliance provides an overall assessment of the thermal efficiency of the homes. Since modular homes have been shown (as discussed below) to be less energy efficient than site built homes, a high penetration of modular homes may be linked to smaller homes and lower RBES compliance.

[1] The estimated number of new homes built in 2000 is from an analysis of the 411 forms collected by the Department of Property Valuation from the towns in Vermont. This analysis covers the same period as the grand lists used to develop the sample frames.

Table 5.2: Comparison of General House Characteristics by Region

	# of Homes	Mean House Size	Pass Code	Modular	Percent Modular	# Homes with % Glazing[2]	Median % Glazing
NW	103	2,489	61%	17	17%	87	13.0%
NE	9	2,265	56%	1	11%	8	12.5%
SW	22	2,929	63%	4	18%	22	17.0%
SE	24	2,247	41%	5	21%	22	14.0%
Totals	158	2,510	58%	27	17%	139	13.0%

This analysis indicates that larger homes with more glazing are being built in the southwest section of the state. Both the house size and the mean percentage of glazing are higher for the southwest at the 95% confidence level when compared to the rest of the sample. Other possible conclusions are not as clear. The variations in house sizes in the northwest, northeast and southeast are not statistically significant. The homes in the southeast appear to have complied with the RBES code at a lower level in comparison to the rest of the sample, but this result is barely significant at the 90% confidence level. The penetration of modular homes does not vary sufficiently to conclude that one region has more modular housing than another. The northwest does not stand out as different from the other regions.

To assess whether these geographical variations may affect the results of the study, the mean home size and percent of homes passing RBES were calculated using values weighted to match the estimated actual distribution by region. The weighted mean home size was 2,515 square feet, as compared to 2,510 for the unweighted sample, and the percent of homes passing RBES was 57%, as compared to 58%. These differences are well within the margin of error of the sample.

Most of the survey respondents were living in primary homes and the results of the study are likely to be more representative of this group. Only seven of the homes in the survey were second homes. These homes were distributed throughout the state, with 3 in the northwest, 2 in the southwest, and one each in the northeast and southeast. The Department of Public Service estimates that 15% of the existing housing market is not primary homes. This estimate seems to indicate that it is likely the second home market is underrepresented in this sample. Scheduling on site visits with homeowners who do not actually live in state represents substantial obstacles, which may contribute to their low representation in this study. The subsample of second homes is too small to draw inferences about this population.

5.2 HOUSE SIZE

5.1 SIZE AND HOUSE CHARACTERISTICS

On average, the surveyed homes had 3.1 occupants and 3.2 bedrooms per home.

[2] Number of homes where the percent glazing as a total of wall area was available. This information was not available for the 19 homes with previous energy ratings.

The median home size is 2,510 square feet of heated area (excluding garage space) with a 95% confidence interval of 2,284 to 2,545 square feet. The average home size in the 1995 baseline study (2,380) is within this confidence interval. The difference in the means may be partially due to variations in measuring and defining heated space. In the current study, conditioned space included heated basement area that may not be finished, as opposed to the 1995 study in which the area measurements included only living area.

There is a trend toward heating and using basement areas. In the 1995 study, 36% of the homes had heated basements, and finished basements accounted for only 18% of the total homes in the survey. In contrast, the current study shows that about half of the homes had heated basements, and auditors reported that most of these basements had at least some finished area. Nine of the 11 largest homes have heated basements.

Table 5.3: Occupany and Average House Size

	Mean	Median	Minimum	Maximum
# of bedrooms	3.2	3	2	6
# of occupants	3.1	3	1	7
Heated area	2,510	2,390	1,067	5,340
1995 study living area	2,380	2,130	804	8,812

The median size home for Vermont Star Homes participants was 2,460 square feet and the average was 2,527. The mean of the Vermont Star Homes group is not statistically different from the sample as a whole.

The table below shows the distribution of the house sizes.

Table 5.4: Distribution of House Sizes

Area (sq. ft.)	2002 Study Heated Area	1995 Study Living Area	2002 VTStar Only
less than 1,000	0%	4%	0%
1,000 to 1,499	8%	12%	9%
1,500 to 1,999	25%	29%	15%
2,000 to 2,499	25%	21%	26%
2,500 to 2,999	19%	11%	30%
3,000 to 3,499	9%	10%	9%
3,500 to 3,999	8%	6%	9%
4,000 to 4,499	3%	4%	0%
4,500 to 4,999	2%	2%	0%
greater than 5000	2%	2%	2%

HOUSE AND CONSTRUCTION TYPES

5.3 CONSTRUCTION TYPE

Most of the homes (90%) fell into four categories: cape, colonial, contemporary and ranch. The seven log homes accounted for 4% of the surveyed new homes.

The most common construction type was wood framed, 16” on center (116 homes or 73%). The remainder consisted of wood framed 24” on center (25 homes or 16%), stress skins (8 homes or 5%), log (7 homes) and other (2 homes). All of the wood-framed homes had 2” by 6” walls. In the 1995 study, the stud spacing was not one of the collected data points, so it is not possible to compare these results to the previous survey. It is, however, possible to compare the incidence of log homes and stress skins. This comparison shows the percentage of log homes and homes built with stress skins is fairly consistent.

Table 5.5: Penetration of Log Homes and Homes with Stress Skins

Construction Type	1995 Study # of homes	1995 Study %	2002 Study # of homes	2002 Study %
N	151		159	
Log	5	3%	7	4%
Stress Skins	5	3%	8	5%

VENTILATION

5.4 MANUFACTURED AND OWNER-BUILT HOMES

5.1 MODULAR AND OWNER-BUILT HOMES

About 23% of the sample (37 homes) were owner built, which is consistent with the results of the telephone survey (22%). Twenty-seven homes (or 17%) were manufactured homes, either double wides or modular homes, as compared to 16% for the telephone survey. It is possible that both the telephone and on site surveys underestimated the incidence of manufactured housing.[3] Using the on site survey to estimate the incidence of manufactured homes in the market and

[3] The telephone survey may have underestimated manufactured homes because comparison of the overlapping on site to the telephone sample indicates that fewer homes were identified as manufactured on the telephone survey than were verified in the on sites. The reasons for possible undercounting from the on site survey is due to the initial exclusion of double wide manufactured homes set on a permanent foundation (they were included later since the RBES code is applicable) and the identification of manufactured homes through auditors’ notes and finding the name of a company making these manufactured homes in the “builder” field rather than as a distinct data point.

setting our confidence level at 95% would lead us to conclude that 17% +/- 6% of the new homes are manufactured homes.

In a number of respects, the efficiency levels of manufactured homes were lower than site built homes. Only about 40% of the manufactured homes in the survey passed the RBES compliance as measured by the VTCheck software, as opposed to over 60% of site built homes. Although the overall incidence of electric water heaters was low, most of these units were installed in modular and owner-built homes. The high saturation of electric stand alone tanks in manufactured homes is likely to be related to the higher percentage of homes with furnaces. Another item of note is that the manufactured homes generally had heating systems with lower efficiencies.

Table 5.6: DHW Fuel Choice and Heating System Efficiencies in Manufactured and Owner-Built Homes

	n	Electric DHW	% EDHW	Furnaces	% Homes	Furnaces % Homes AFUE<=.85	Boilers % Homes AFUE<=.83
Manufactured Homes	26	7	27%	9	35%	100%	40%
Owner-Built	36	3	8%	2	6%	50%	28%
Builder & Spec Homes	96	2	2%	12	12%	0%	24%
All Homes	158	12	8%	23	15%	42%	34%

Although modular homes generally were less energy efficient than site-built homes, they were also significantly smaller and had a lower percentage of glazing in comparison to total wall area, as shown in Table 5.7 below. In contrast, owner-built homes tended to be larger in comparison to the rest of the sample, and nine of the twenty-one homes over 3,500 square feet were built by the homeowner.

Table 5.7: House Size and Percent Glazing for Manufactured and Owner-Built Homes

	# homes	Average % glazing	# homes	Mean House Size	Median House Size
Manufactured Homes	27	13.2%	27	1882	1663
Owner-Built	36	14.9%	37	2835	2492
Builder & Spec Homes	76	14.8%	94	2562	2407
All Homes	139	14.5%	158	2510	2391

BLOWER DOOR TESTS AND VENTILATION ISSUES

5.5 Program Participation

5.1 PROGRAM PARTICIPATION

Homeowners' Perceptions: 47 of the 158 homeowners reported that their homes had been through the Vermont Star Homes program, with 27 claiming that the home received a home energy rating. A total of 18 homes were served through utility programs. The distribution among the programs is given below.

Table 5.8: Vermont Star Homes and Utility Program Participation

	Overall	VtStar	Rated Homes
n	159	47	27
VGS	12	12	12
BED/VGS	4	3	2
WEC	4	2	0
Don't Know	21	2	3
None	116	26	9
Blank	2	2	1

According to these customer reports, about 18% of the homes received energy ratings, as compared to about 12% of the respondents to the telephone survey. However, further investigation suggests that information provided by the on site respondents may overstate the number of energy ratings and program participation. Of the 27 customer-reported ratings, 6 could not be verified by Vermont Star Homes. Two of these six were participants in the Vermont Star Homes program but did not receive ratings. Three of the six were identified as VGS participants but could not be verified by VGS.

Direct conversations with two participants and two builders indicates that some builders are claiming that homes have been rated when, in fact, these specific homes did not receive energy ratings. In one case, the builder has a history of participating in the program and constructing homes to the program standard, but another builder has not chosen to participate in the program to date.

It is equally possible that some homeowners are not aware that their homes were served through the program. An initial review by Efficiency Vermont indicates that 3 additional homes participated in the program on some level. Matching the survey participants to program participants is an inexact science due to the different methods of recoding locations.

5.6 Act 250 and Developments

According to participant responses, 30% of the homes in the sample went through the Act 250 process. About 60% of homeowners reported that their homes did not go through Act 250, and the remaining 20% was unsure.

Table 5.9 Act 250 Homes and Homes in Developments

	All Homes		In Developments	
	# homes	% homes	# homes	% homes
Act 250	48	30%	39	53%
Non Act 250	93	59%	23	31%
Don't know/blank	17	11%	12	16%
Total	158	100%	74	47%

Almost half of the homeowners in the survey identified their homes as located in developments. Of these home, over half were subject to Act 250.

Act 250 homes tended to be smaller than the homes that did not go through Act 250, with a mean of 2370 square feet (median of 2170) for Act 250 as compared to a mean of 2620 (median of 2470) for non Act 250 homes. Only two of the twenty-one homes over 3500 square feet went through Act 250.

5.7 FIREPLACES

Almost half the homes (76 out of 159) had at least one fireplace, with 6 homes containing two fireplaces. In 39 homes of these homes, the fireplace(s) had tightly fitted doors, and 46 homes had designated air supply for the fireplace(s).

5.8 MUNICIPAL WATER AND SEWAGE HOOK UPS

5.1 MUNICIPAL WATER/SEWE

Of the 159 surveys, 54 homes (34%) were on a municipal water system and 45 homes (28%) were tied into a municipal sewer system.

6

RBES CODE COMPLIANCE AND THERMAL SHELL CHARACTERISTICS

This section discusses the survey results related to code awareness, code compliance and thermal shell characteristics.

6.1 RBES AWARENESS

6.2

About 35% of homeowners stated that their home complies with the RBES code. Another 25% of survey respondents had no opinion on code compliance, stating that they were unfamiliar with RBES. The RBES certificate was actually observed displayed in about 18% of the homes overall, as compared to the 25% of homeowners who claimed to have certificates in the phone survey. Not surprisingly, Vermont Star Homes program participants were more likely to report that their homes complied with RBES, and were more likely to have the RBES certificated displayed. As discussed in more detail in Section 6.2 below, four of the homes with RBES certificates displayed actually failed to meet the RBES standard by a fairly wide margin.

Table 6.1: Homeowners' Perception of RBES Compliance

	All Respondents		VT Star Home		Rated Homes	
	#	%	#	%	#	%
N	159		47		21	
say new homes complies	56	35%	31	66%	16	76%
say home does not comply	12	8%	2	4%	1	5%
not sure if home complies	51	32%	6	13%	3	14%
not familiar with RBES	40	25%	8	17%	1	5%
RBES certificate displayed	28	18%	19	40%	4	19%

6.2 RBES COMPLIANCE

Of the 158 homes in the sample, 92, or 58% +/- 8%, meet the standards of the Vermont Residential Building Efficiency Standard (RBES). Of these homes, compliance was determined for 139 using the VTCheck methodology of U values multiplied by the areas of building components to obtain UA values for all building components. Seventy-three of these homes were determined to meet the standard. Another 19 homes had received energy ratings through the Vermont Star program that demonstrated their compliance with RBES. Many homes are clustered around the RBES compliance criteria, with almost one third (51 homes) within 10% on either side of the RBES code.

The percentage of homes passing RBES shows an improvement over the 1995 baseline study, in which 35% to 40% of the homes were estimated to pass the RBES code. The characteristics of the homes failing to meet the standard were reviewed to assess any patterns in noncompliance. As in 1995, lack of foundation insulation, both basements and slabs, is a leading reason for failing to meet the code. A total of 53 homes lacked foundation insulation on at least some portion of their foundation and in 45 homes the area involved exceeded 20 feet of perimeter. Another major factor contributing to noncompliance was a high percentage of glazing and doors to wall area. About 40% of the homes that failed to meet the compliance criteria had window-to-wall proportions of 17% or greater. A less common reason for noncompliance was sporadic instances of missing or inadequate insulation in other envelope areas.

Figure 6.1: RBES Compliance

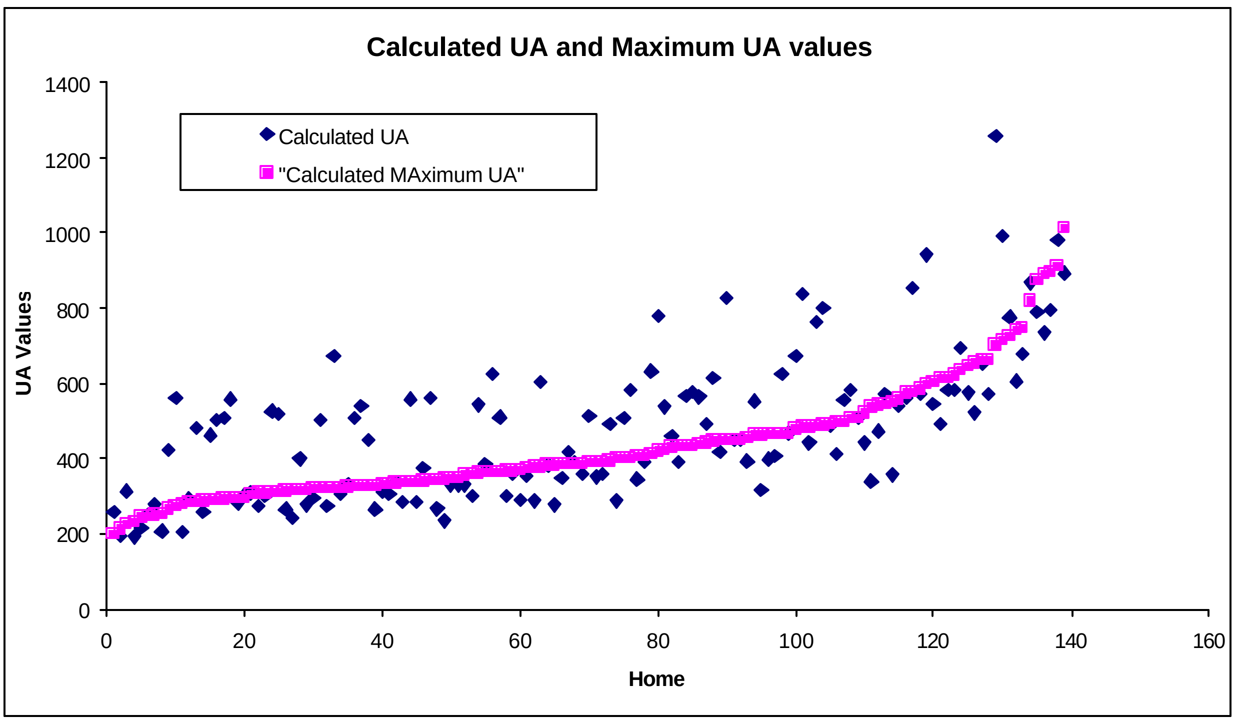


Figure 6.1 is a scatter plot of the UA values as compared to the code-required maximum UA values for each home, calculated for the 139 homes where complete data was collected. The Y-axis shows the UA values, and the X-axis represents each home, in order from lowest to highest allowed UA value. The purple line shows the minimum code compliance, and the dots represent

the actual homes; dots above the line are homes that do not meet the standard, while dots below or on the line comply with the standard.

Larger homes (over the median house size) passed at a higher rate than smaller homes (under the median), 65% to 51%, respectively. This result is significant at the 95% level. This difference may partially reflect a pattern in the results of the VTCheck software indicating that it is slightly easier for larger homes to pass than smaller homes.

Another noteworthy result is that eight of the 28 homes with RBES compliance certificates did not actually meet the code. Four of these homes were very close to passing (within 5%), and it is likely that these homes would have passed with an analysis based on more precise information (such as exact window U-values). However, the other four homes failed by a wide margin.

Homes built under Vermont's Act 250 passed the RBES standard at a nominally higher rate than the survey respondents as a whole, with 32 out of 48 homes (66%) meeting the code and compared to 56% for the non Act 250 homes. This difference in the rate of code compliance between Act 250 and those homes not identified as Act 250 is only marginally significant at the 10% confidence level.

In contrast, manufactured homes passed at a rate that was substantially lower than site built homes (41% as compared to 61%). This difference is statistically significant at the 95% confidence level.

Homes built by owner-builders are notable for their presence on both ends of the spectrum. Many of these homes were at the top of the efficiency ladder, and others were among the least efficient. Of the five homes that exceeded the code requirements by the greatest percentage (by VTCheck standards), three were built by owner builders, and two of the bottom five homes failing the code requirements by the largest margin were constructed by their owners.

6.3 OTHER RBES REQUIREMENTS

The RBES code includes some requirements beyond the thermal shell standard. This study was not designed to provide a comprehensive assessment of compliance with these additional requirements, due to time limitations and the other critical objectives of the site visits. However, the information collected through the site visits does provide some insight into compliance with these items, as list below in Table 6.2.

TABLE 6.2: ADDITIONAL RBES REQUIREMENTS

Other RBES Requirements	Description	Compliance Issues
Air Leakage	Seal joints, access holes, connections; standards for recessed lights	Houses generally very tight; only 28% over .31 air changes per hour; compliance with recessed light standard unknown
Vapor Retarders	Installed in all non-vented framing components	Attics generally vented; vapor barriers common in walls
Duct Insulation	Ducts in unconditioned space insulated to R-5	Ducts predominantly installed within thermal barrier; 1 home with uninsulated, unsealed ducts in unconditioned space
Duct Sealing	Ducts in unconditioned space must be sealed with mastic	See above
HVAC System Efficiency & Balancing	Minimum AFUE of .78 for furnaces, .80 for boilers; must have means for balancing	All homes met minimum AFUE requirement; no information on balancing is available.
Temperature Controls	Each HVAC zone must have a thermostat	All homes met this requirement
HVAC Piping Insulation	HVAC pipes insulated in unconditioned space	HVAC pipes predominantly installed within thermal barrier; 3 homes with uninsulated pipes in unconditioned space
Swimming Pools	Timer on pump, heater on/off switch and cover for heated pools	Only two homes with pools; compliance unknown
DHW	Meet minimum federal standard from 1992, minimum R-value of R-14; heat traps or pipe insulation for stand alone tanks.	All homes met federal standards; three homes had external tank wrap.
Fireplaces	Fireplaces must have one of the following: tight-fitted doors or chimney damper, or chimney cap damper.	50% of homes had fireplaces; about half of homes with fireplaces have tight doors, about two-thirds have designated air
Exhaust Fans	Dampers required for bath, kitchen and dryer fans.	Compliance unknown
Certification	Certificate displayed in home, sent to state and town clerk	Low certification rate (18% displayed in home)

6.4 Mechanical Ventilation

VENTILATION

Of the 157 homes in the survey with complete ventilation data, 11 homes contained HRV's and 39 had exhaust fans on a timer control, for a total of 45 homes with a whole house ventilation system.[1] This result indicates that 29% of the homes had a whole house ventilation system, which represents a substantial increase from the 6% homes in the 1995 baseline study.

The majority of the ventilation systems are exhaust fans with timers. The increase in this type of ventilation seems to be largely driven by the efficiency programs, i.e., Vermont Star Homes Program, Vermont Gas's HomeBase Program, Washington Electric Coop's and Burlington Electric Department's residential new construction programs.[2] Table 6.2 shows that 70% of homes that were constructed with the assistance of one of these efficiency programs have a whole house ventilation system, as compared to 15% of the nonparticipating homes.

Table 6.3: Whole House Ventilation Systems

	All	Program Participants	Nonparticipants
N	157	50	107
HRV's	11	4	7
Exhaust fan/control	40	31	9
Total ventilation systems	51	35	16
% homes with ventilation systems	29%	70%	15%

Homeowners' perceptions: 34 homeowners (21% of the 157) reported that their homes had whole house ventilation. In eight (8) of these homes (24% of the 33), the homeowners indicated either that the control system was not used or that they were not familiar with the operation of the control system. (In at least one case, the auditor instructed the homeowner on the correct use of the controls.)

Comparing the homeowners' perceptions with the survey results showed that the 34 homeowners did accurately identify their homes as having a whole house ventilation system. In contrast, in 17 homes with ventilation systems, the homeowner apparently was unaware of it. Eleven of these homes were built by program participants.

[1] Some homes with HRV's also had an exhaust fan on a timer control.

[2] Whole house ventilation is required to meet the Vermont Star Home designation, and exhaust fans with timers are frequently recommended as a cost effective way to meet this standard. All of the programs have similar requirements.

BLOWER DOOR TESTS AND VENTILATION ISSUES

6.5 Blower Door Test Results and Ventilation Issues

In general, the homes were tightly built, with over two-thirds of the homes below .31 natural air changes per hour. There were a very limited number of homes with infiltration problems.

Table 6.4: Blower Door Test Results

Natural Air Changes per Hour	Combined Total (# of homes)	ASHRAE Method[3] (# of homes)	ERH Method (# of homes)
N	156	137	19
Less than .31	103	84	19
.31 to .50	35	35	0
More than .50	9	9	0
Mean	.27	.28	.22
Median	.25	.26	.22
Minimum	.04	.04	.09
Maximum	1.00	1.00	.31

Although the homes are tight, they generally meet the ASHRAE Standard 62 guidelines for air flow at the current occupancy levels.[4] Only 6% of the homes failed to meet the standard and did not have a whole house ventilation system. In addition to the effectiveness of the efficiency programs in encouraging the installation of ventilation equipment, this result may also be an unintended consequence of the trend toward large homes.

If the homes are assumed to be fully occupied at two people per bedroom, 44 of the 156 or 28% fail to meet the ASHRAE criteria.

[3] The ASHRAE method involved averaging the results from pressurization and depressurization tests. Using this method allows comparison to the ventilation requirement set out in ASHRAE standard 62. The ERH blower door tests were based only on a depressurization test. More detail is provided in Section 4.

[4] Standard 62 requires 15 cfm per person. Consequently, the level of occupancy of the house has an impact on the air flow requirements.

For 136 homes, both pressurization and depressurization tests were performed (as discussed above). For almost all of these homes, these two tests produced different results, with the depressurization test higher in 39% (53) of the homes and lower in 56% (76). In a majority of the homes (63% or 85 homes), the cfm50 measurement made during the pressurization test was more than 10% different from the depressurization test, and in 17% (23 homes) the difference was 30% or more. The reasons for these differences are not readily apparent from the data collected in this study. These results indicate that averaging the two tests is likely to produce a more accurate assessment of air leakage than the depressurization test alone.

BLOWER DOOR TESTS AND VENTILATION ISSUES

6.6 INSULATION LEVELS

Attic and wall insulation met or exceeded prescriptive code levels for the majority of homes. These results are similar to the 1995 baseline study, indicating that attic and wall insulation practices have not changed substantially since the RBES code was instituted.

As can be seen from the table below (Table 6.2), there is still room for improvement in attic insulation, with 36% of the slopes underinsulated in comparison to the minimum prescriptive code requirement. However, homes generally did not have multiple deficiencies in the thermal shell, i.e., these substandard conditions were sporadic and not found grouped in particular homes or types of homes. For example, a slope area in one home may have been underinsulated, but the attic flats and wall insulation levels were consistent with the RBES code or better. Also, a large majority of homes that failed to meet the RBES code had R-values close to the standard.

Walls were insulated to R-19 or better in 90% of the homes. This result is highly consistent with the 1995 baseline study, which found that 94% of the homes in that sample had R-19 or better in the main walls.

Table 6.5: Attic and Wall Insulation Levels

	Attic Flats	Slopes	Kneewalls	Walls
Total Homes	141	113	34	158
R-value Below Code	28%	36%	21%	10%
R-value Meet or Exceed Code	68%	64%	79%	90%
Minimum	15	19	0	8
Maximum	83	60	32	40
Median	38	30	19	19
Mean	40	32	19	20
Average Area (sq. ft.)[5]	1,115	775	297	1,931
Minimum RBES Requirement[6] (Prescriptive Path)	R-38	R-30	R-19	R-19

Comparison to the 1995 study suggests that basement insulation is becoming much more common. Over 60% of the homes in the current study had foundation wall insulation meeting the RBES minimum prescriptive level of R-10, as compared to less than half in the 1995 study.

However, even with these improved construction practices, basement walls were found without any insulation in about 25% of the homes, the slab edge of a walkout basement was almost always left without insulation and a number of homes had incomplete foundation insulation not reflected in the nominal R-values, i.e., a number of the homes that meet the nominal R-value requirement of the RBES code still have deficiencies in the basement insulation. Unlike attics and walls, most of the homes failing the RBES prescriptive standard had little or no basement insulation.

[5] Areas of the house components were not available for the 19 Vermont Star Homes participants for whom program data was substituted for direct data collection. The average area excludes these participants.

[6] The prescriptive code path allows for numerous ways to meet the code. These value represent the minimum and the builder may be required to increase the of other house components to meet the standard.

Table 6.5: Basement Insulation Levels

	Basement Walls	Exposed Floors	Floor over Unconditioned Space	Slab
Total Homes	146	26	45	63
R-value Below Code	38%	73%	67%	63%
R-value Meet or Exceed Code	62%	23%	33%	37%
Minimum R-value	0	8	0	0
Maximum R-value	29	43	45	11
Median R-value	10	30	28	0
Mean R-value	8	30	25	4
Average Area (sq. ft.) (see footnote 1)	1036	134	629	N/A
Minimum Code Requirement (see footnote 2) (Prescriptive Path)	R-10	R-38	R-30	R-10

BLOWER DOOR TESTS AND VENTILATION ISSUES

6.7 WINDOW AND DOOR GLAZING

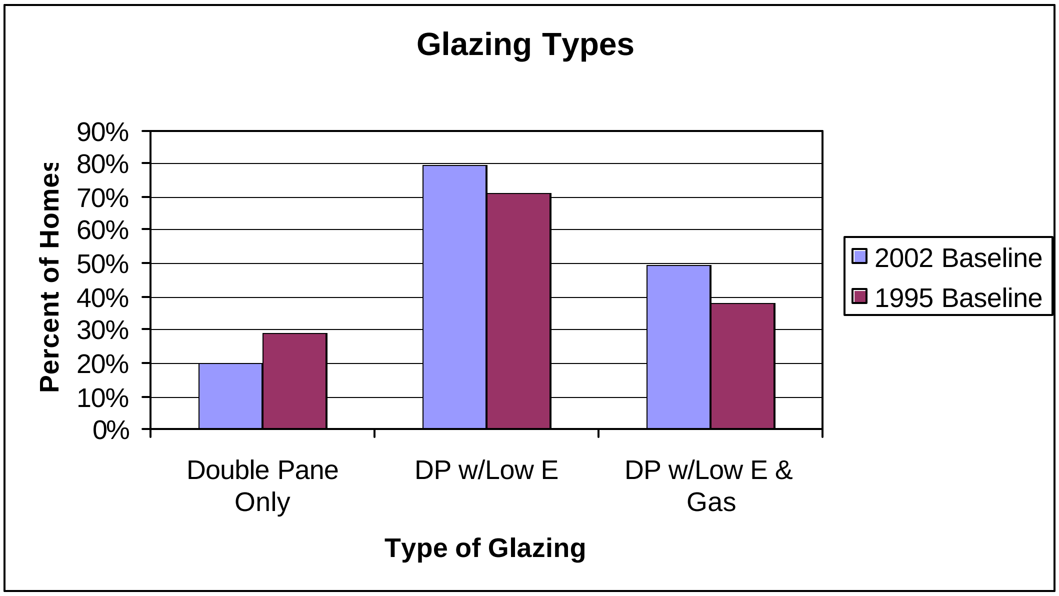
Double pane windows with Low-E glass is the most common choice for glazing among survey respondents, with about 80% of the homes having low-E glazing on 75% or more of their window area (126 of 158). High efficiency glazing with both Low E and argon gas were the predominant choice in about 50% (78) of these homes. The remainder of the surveyed homes (about 20%) had double pane without Low E or argon. The break out of the percent of glazing in windows and doors is depicted graphically in Figure 6.2.

Considering only the 139 homes that received full site visits, about 80% of all glazing area contained Low-E and 58% contained both low-E and argon gas. While windows with low-E and argon gas are a common occurrence, there were very few instances of higher efficiency windows such as triple pane with low E. Six door units and one window unit contained triple pane glass, for a total glazing area of 83 sq ft.

Single pane windows were rare. Only one home contained single pane windows with low E storms.

In comparison, the 1995 study indicated that about 70% of the homes had windows with low E and less than 40% had low E and argon. The increases in the percentages of Low E and gas filled windows between the 1995 and 2002 studies are significant at the 5% level. The results of the 2002 study indicate that the market has been continuing to move toward more efficient windows.

Figure 6.2: Glazing Types



While window efficiency has been improving, houses also have substantially more window area. In general, homes have a greater ratio of glazing to wall area than found in the 1995 study, as shown in Table 6.5 below. The 1995 study showed that almost a quarter of the homes had less than .10 glazing in comparison to the wall area, and only 15% of the homes had more than a .15 glazing ratio. In the current study, this trend is reversed, with only 10% of the homes having a glazing to wall area ratio of less than .10 and 35% of the homes having more than .15 glazing.[7]

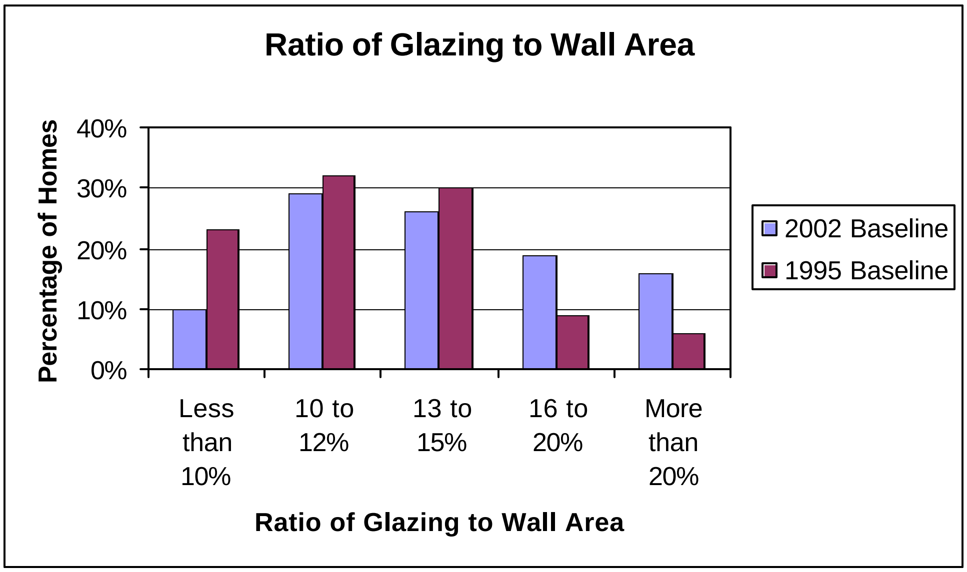
Table 6.6: Ratio of Glazing to Wall Area

	2002 Baseline Study		1995 Baseline Study
Window to Wall Area Ratio	Number of Homes	Percentage of Homes	Percentage of Homes
N	139		
Less than 10%	14	10%	23%
10 to 12%	41	29%	32%
13 to 15%	36	26%	30%

[7] The percentages for the 2002 study are based on the 139 homes with full site visits. There was not sufficient information to determine the percentage of glazing to wall area for the 19 homes where the shell data were obtained from the energy rating.

16 to 20%	26	19%	9%
More than 20%	22	16%	6%
Mean	6%		
Median	27%		
Minimum	14%		
Maximum	13%		

Figure 6.3: Graph of Ratio of Glazing to Wall Area



This trend toward higher glazing ratio is particularly prevalent in larger houses. The mean house size of homes with a glazing-to-wall ratio of less than .17 is 2380 square feet (99 homes), as compared to an average size of 2750 square feet for homes with .17 or more (40 homes). This difference between house sizes is significant at the 95% confidence level.

7 EQUIPMENT CHARACTERISTICS

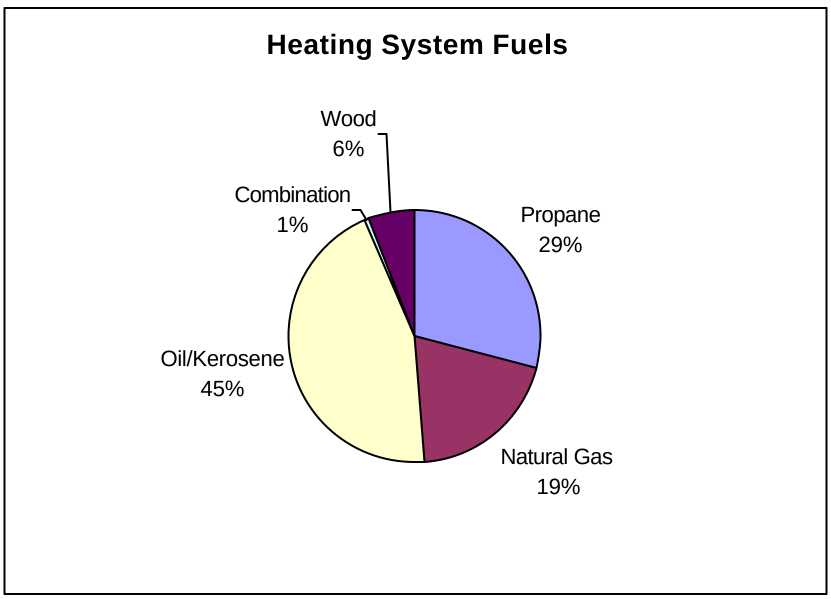
This section discusses the survey results related to equipment and fuel choices for space and water heating.

7.1 SPACE HEATING SYSTEMS

HEATING SYSTEMS

As also found in the 1995 baseline study and the telephone survey, oil is the predominant heating fuel, with 45% of the homes using oil or kerosene as the primary fuel. The primary central heating systems used propane in 29% of the homes, natural gas in 19%, wood in 6%.[1]

Figure 7.1: Primary Heating System Fuels



Most of the 154 homes with complete system information have hydronic systems (83%, 126 homes), with 67% of those homes selecting baseboard, 21% radiant and the remainder a combination of the two. Furnaces were the central system of choice in 22 homes (14%). These results are consistent with the 1995 baseline survey. Boilers were much more likely to be fueled by oil, while furnaces were more commonly designed for propane or natural gas.

Forty-five percent of the homes (61) have a secondary heating system, with wood stoves the most common (in 32 homes), followed by propane or natural gas stoves (16 homes), space

[1] These percentages are based on 154 homes. We were unable to ascertain the primary heating fuel for four homes.

heaters (6 homes) including two homes with electric space heaters, and fossil fuel central systems used as secondary systems in seven homes.

About half of the central heating plants were sealed combustion, and over half were direct vent. Only one home with a furnace had unsealed ducts outside of the conditioned space. Four homes had uninsulated distribution systems outside of the conditioned space.

The vast majority of the central heating systems have an AFUE above the minimum code requirement of .80. More than half of the systems are in the mid range of .83 to .87. For furnaces, almost half are in the two bottom bins and the rest in the highest efficiency category, possibly reflecting the relative scarcity of mid range efficiency furnaces on the market.

Overall, there is an improvement in efficiencies since the 1995 study. The minimum AFUE was raised from .70 to .78 and the median increased from .84 to .85.

Table 7.1: AFUE of Central Systems

	All Systems		Boilers		Furnaces		Manufactured Homes	
Range	#	%	#	%	#	%	#	%
Total Homes	140		120		20		24	
< 0.780	0	0%	0	0%	0	0%	0	0%
0.780 to < 0.800	5	4%	0	0%	5	25%	5	21%
0.800 to < 0.830	27	19%	24	20%	3	15%	8	33%
0.830 to < 0.870	78	56%	78	65%	0	0%	11	46%
0.870 to < 0.910	18	13%	18	15%	0	0%	0	0%
>= 0.910	12	9%	0	0%	12	60%	0	0%
Minimum	0.780		0.802		0.780		0.780	
Maximum	0.930		0.890		0.930		0.862	
Median	0.850		0.850		0.910		0.821	
Mean	0.850		0.848		0.865		0.821	

Most homes (80%)[2] had more than multiple heating zones, ranging from two to eight zones. Less than half of the homes (43%) had at least one setback thermostat.

7.2 HEATING SYSTEM SIZING

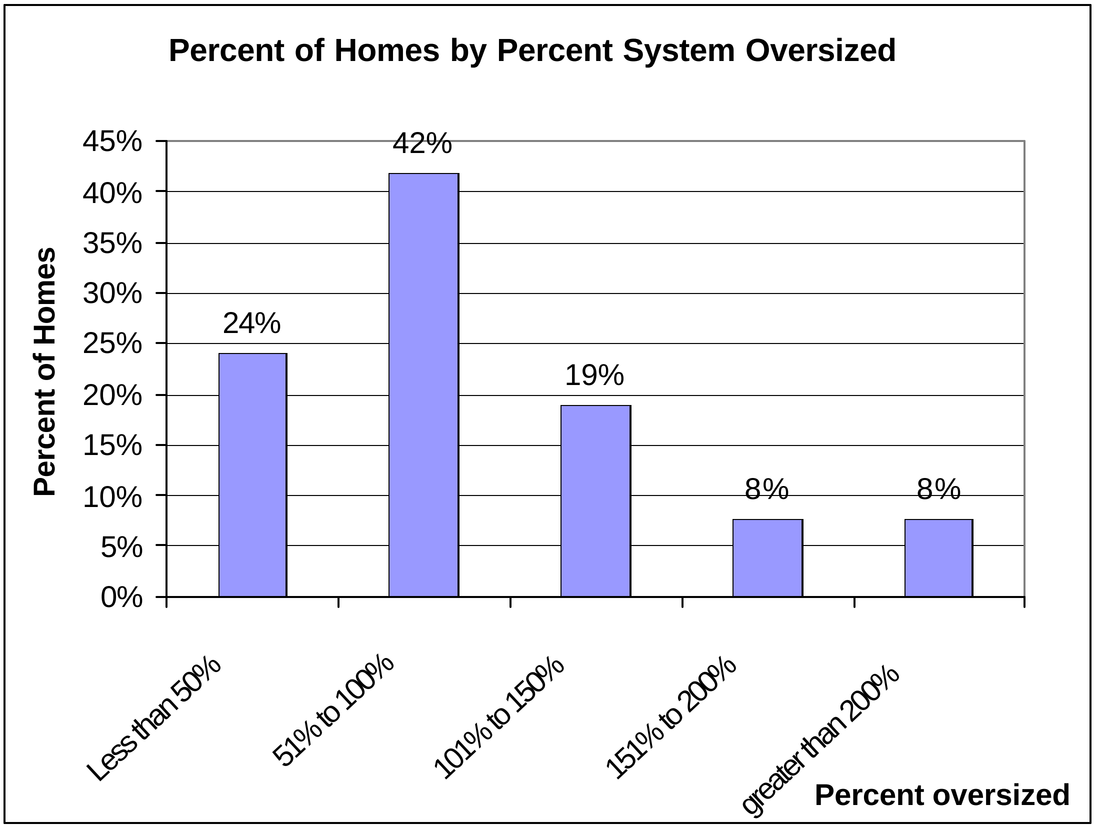
HEATING SYSTEM SIZING

[2] These numbers do not include the efficiency program participants where only partial data was collected since this information was not available from the program database.

We compared the sizing of the heating system output to the design load requirement for 117 homes in the sample. If domestic hot water was also provided by the system, i.e., integrated or tankless coil, the DHW load was added to the design load. Systems were considered correctly sized (oversizing percent is 0) if they were at or near 125% of the design load.

As in the 1995 baseline study, heating systems were consistently oversized.[3] Only 7 of the 117 or 6% were correctly sized. The graph in Figure 7.2 breaks out the homes into bins depending on the output capacity of the heating equipment as a percentage of the calculated maximum load.

Figure 7.2: Heating System Sizing



The median oversizing was 81%, approaching twice as much heating output as required by the load plus 25%. Only 7% of the homes had systems that were properly sized, as opposed to 35% with systems that are more than twice as large as needed. Excessive oversizing of the heating system results in a reduction in seasonal efficiency. This market trend highlights the potential for efficiency improvements by promoting the correct sizing of heating equipment.

[3] Defined as (System Output – (Design load * 1.25))/(Design load * 1.25)

For the most part, as shown in Table 7.2, oversizing is fairly consistent across fuel type. Natural gas may be the one exception, and this result may be attributed both to the VGS New Construction Program and the availability of lower capacity equipment for gas.

Many of the same issues mentioned in the 1995 study contribute to the oversizing of boilers and furnaces. Equipment is not made for homes with very small design loads. Gas and LP Boilers start at outputs of 30,000 while oil boilers have minimum outputs of 56,000 BTU's. There are a few natural gas and propane furnaces available with outputs below 30,000 BTU.[4] However, the lack of smaller equipment does not explain the huge gap in the output of the installed equipment in comparison to the design load. The major factor in system oversizing is likely to be the tendency of contractors to oversize the equipment.

Table 7.2: Average Heating System Oversizing

Fuel Type	Oil	LP	NG	Kerosene	All
# of Homes	59	38	14	5	116
Design Load	53,394	41,870	43,111	32,390	47,604
System Output	118,920	96,536	87,857	68,000	106,618
Average Oversize	95%	107%	69%	85%	95%

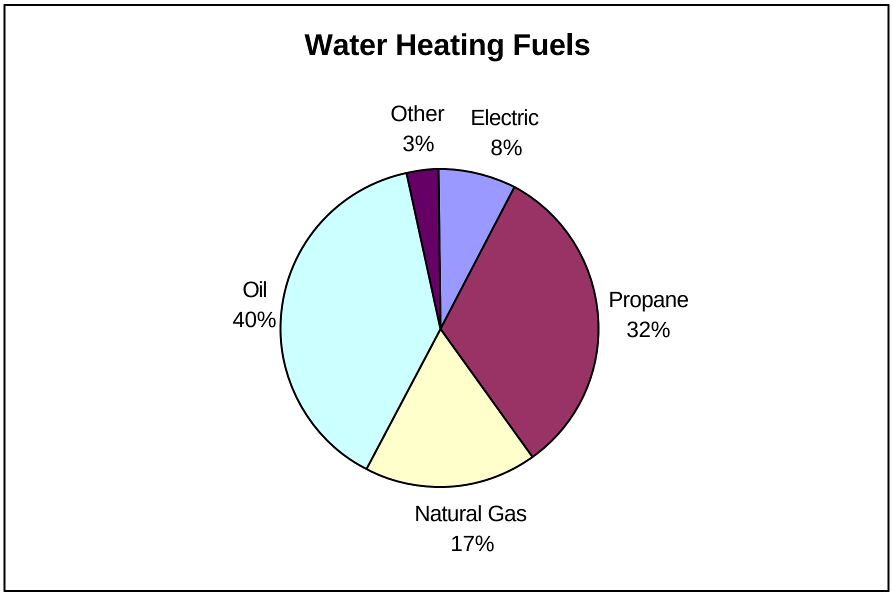
7.3 WATER HEATING

DHW SYSTEMS

As for space heating systems, oil was the most commonly chosen fuel for water heating, with 40% of the homes using oil, followed by propane with 32%, natural gas with 17%, electric (8%) and the remainder split among wood, kerosene and solar (one home). The penetration of electric tanks closely matches the 1995 baseline study.

[4] GAMA directory April 2001.

Figure 7.3: Water Heating Fuels



The incidence of electric water heaters occurs much more frequently in manufactured housing than in the general sample. Seven of the twelve homes with electric DHW were found in manufactured homes, and these seven homes represent almost 40% of the eighteen manufactured homes included in the survey.

Integrated, indirect fired tanks dominated (76% of the homes), with stand alone tanks accounting for 20%, tankless coils at 3% and on demand (1%). This distribution represents a remarkable improvement from the 1995 study, in which almost 30% of the water heaters were low efficiency tankless coils. Since the RBES code does not specific minimum efficiency standards for hot water systems, this result may be related to other economic factors, such as the degradation of tankless coil systems due to the mineral-laden water common in Vermont, in addition to a trend toward greater efficiency.

Comparing the hot water system with the heating plant shows that integrated, indirect-fired tanks were installed with 90% of the boilers.

Table 7.3: DHW and Heating System Types

	DHW System				
Heating Plant	Integrated	On Demand	Stand Alone	Tankless Coil	Totals
Boiler	120	0	8	5	133
Furnace	0	1	22	0	23
Totals	120	1	30	5	

The overall result of this trend is greater efficiency in hot water production. Of the 132 systems with known efficiency, average energy factor was .75. Table 7.4 provides a breakout of efficiency ranges by system type and fuel type for the 132 systems with complete DHW system information.

Table 7.4: DHW Energy Factors

System Type	# of	Average Energy Factor	Median	Minimum	Maximum
Integrated	109	77%	77%	70%	81%
Oil	56	77%	77%	72%	80%
LP/NG	53	76%	77%	70%	81%
Stand Alone	23	70%	64%	50%	91%
LP & NG	15	60%	61%	50%	76%
Electric[5]	8	88%	88%	86%	91%

[5] Energy Factors for electric stand alone tanks do not account for inefficiencies in the production or distribution of electricity. Consequently they are not directly comparable to oil and gas efficiencies, which have a greater similarity in terms of distribution and production.

8 LIGHTING AND APPLIANCES

This section presents the findings on lighting characteristics and the penetration of efficient appliances.

8.1 LIGHTING

LIGHTING

About 34 hardwired light fixtures were installed per home, showing an increase over the 25 fixtures per home from the 1995 baseline. The greater number of fixtures could be partially related to the increase in house size from the earlier study to the current one, although the increase in the number of fixtures is proportionally much larger than the increase in house size, indicating that other factors may be influencing the number of fixtures installed. Vermont Star Home and utility program participants had a slightly higher number of total fixtures (36) than nonparticipants (33).

For all the surveyed homes, about 8% of the fixtures contained compact fluorescent and 6% other fluorescent lamps. This result shows an improvement over the 1995 baseline study, which indicated that 5% of the fixtures were compact fluorescent and 4% were other fluorescents.

The Vermont Star Homes and utility programs were clearly a driver in promoting the installation of fixtures with compact fluorescent lamps. Participation in the Vermont Star Homes program and other utility programs increased the penetration of fixtures with compact fluorescent to 16%, whereas nonparticipating homes achieved an installation rate of only 4%. The penetration of other nonincandescent lighting was approximately the same between the two groups.

Table 8.1: Penetration of Light Fixtures by Lamp Type

	All Survey Respondents		Vermont Star Home and Utility Program Participants		Non Program Participants	
Type of Fixture	#	%	#	%	#	%
Incandescent	4,212	79%	1,278	72%	2,934	83%
Compact fluorescent	438	8%	286	16%	152	4%
Other fluorescent	313	6%	131	7%	185	5%
Low Volt Halogen	190	4%	60	3%	130	4%
Other Halogen	129	2%	28	2%	101	3%
High pressure sodium	5	0%	0	0%	5	0%
Other	23	0%	1	0%	22	1%
Total	5,310		1,784		3,529	

Slightly under half of the homes in the survey installed one or more fixtures with compact fluorescent lamps, as compared to about one-third of the survey respondents of the 1995 study. Program participants were much more likely to install at least one CFL fixture (80% as compared to 31%) and tended to install more CFL fixtures per home than the survey respondents as a whole. About 70% of nonparticipants did not install a single fixture with CFL lamps.

Table 8.2: Distribution of Efficient Fixture per Home

# of CFL	All Survey Participants		Program Participants		Nonparticipants	
Fixtures	# of Homes	%	# of Homes	%	# of Homes	%
0	84	53%	10	20%	74	69%
1to 3	37	23%	15	30%	22	20%
4 to 6	14	9%	6	12%	8	7%
7to 9	10	6%	9	18%	1	1%
10 to15	9	6%	8	16%	1	1%
More than16	4	3%	2	4%	2	2%
n	158		50		108	
Min	0		0		0	
Max	36		36		33	

Overall survey results indicate that CFL fixtures were located fairly equally in likely high use and low use locations.[1] Program participants, however, showed a greater tendency to place CFL fixtures in high use locations (43% of CFL fixtures in high use sites, as compared to 32% in low use areas), whereas nonparticipants were more likely to place CFL fixtures in low use locations (24% in high and 32% in low use areas).

Approximately 7% of exterior light fixtures contained CFL lamps. This percentage is reasonably consistent between program participants and nonparticipants.

PLUG LOAD LIGHTING

On average, the surveyed homes had 8 plug load lamps, and 4% contained CFL bulbs. The saturation of CFL technology in plug load lighting was similar in the homes of program participants and nonparticipants. These lamps were generally located in high use locations for both groups.

8.2 ENERGY STAR APPLIANCES

APPLIANCES AND AIR CONDITIONING

[1] High use locations were defined as kitchen, living room and family room, and low use sites were halls and bathrooms.

The saturation of Energy Star appliances was high, with 47% of clothes washers, 36% of dishwashers and 27% of refrigerators verified as meeting the Energy Star criteria. Table 8.3 below provides the details of Energy Star appliance saturation for efficiency program for all survey respondents.

Table 8.3: Saturation of Energy Star Appliances

Appliance	Total	# New	# Valid Model Numbers	# Estar	% Estar
Refrigerator	178	150	140	38	27%
Clothes washer	156	101	87	41	47%
Dishwasher	143	130	116	42	36%
Total # of site visits	159				

Dishwashers and refrigerators were most commonly purchased for the new home. Freezers were the most likely to be moved from the previous home, and many of these freezers were quite advanced in years, some over 30 years old. Moved refrigerators also tended to be older models, having a median age of 10 years.

Table 8.4 below shows the difference in saturation rates between efficiency program participants and nonparticipants. The saturation of Energy Star dishwashers in participating homes is markedly higher than nonparticipating homes (49% as compared to 31%). This difference is significant at the 5% level. For clothes washers, participating homes were somewhat more likely to have an Energy star model (56% to 42%), and this increase in saturation is significant at the 10% level. For refrigerators, there was no significant difference between participating and nonparticipating homes.

Table 8.4: Saturation of Energy Star Appliances for Participants and Nonparticipants of Efficiency Programs

	All Homes		Nonprogram Participants		Program Participants	
Appliance	# homes[2]	% homes w/Estar	# homes	% homes w/Estar	# homes	% homes w/Estar
Refrigerator	140	27%	98	26%	42	31%
Clothes washer	87	47%	55	42%	32	56%
Dish washer	116	36%	81	31%	35	49%

2 Number of homes is the number with valid appliance model numbers.

8.3 OTHER APPLIANCES

OTHER APPLIANCES

The vast majority of homes had clothes dryers, and 33% of these appliances used propane or natural gas. In comparison to the 22% of the gas dryer hookups from the 1995 study, this result shows an increase of new homes with non-electric dryers. Gas was the preferred fuel for cooking stoves (57% of homes).

About 15% of the homeowners reported using room air conditioners, and 6% of the homes were built with central air conditioning. The homes with central air conditioning were geographically dispersed throughout the southern, central and northwestern sections of the state.

Hot tubs were as common as central air conditioning, with 10 homes installing hot tubs and a substantial majority (80%) fueled by electricity.

Dehumidifiers were installed in 7% of the homes. Only 2 homes had pools.

Table 8.5: Distribution of Other Appliances

	# homes	% homes	# Items	Electric	Fossil fuel	% Elec
Room A/C	24	15%	32			
Central A/C	10	6%	10			
Hot Tubs	10	6%	10	8	2	80%
Clothes dryer	153	96%	153	103	50	67%
Cooking Stoves	156	98%	156	67	89	43%
Dehumidifiers	11	7%	11			
Pool Pump	2	1%	2			

Ceiling fans are a popular addition to new homes, with 103 homes (65%) of the sample containing at least one, and 43 of the 103 homes containing three or more. A total of 258 ceiling fans were installed in the 103 homes.

9 COMPARISON OF ON SITE AND PHONE SURVEY RESULTS

This section compares the results of the telephone survey to the on site survey in a few key areas, such as house size, heating fuels and systems and manufactured housing

9.1 OVERVIEW

The telephone survey was larger than the on site (200 and compared to 158), also less intrusive and may possibly be more representative of the market. However, the on site data were collected by unbiased, experienced energy auditors, and may be more accurate. There are two major question arising:

1. Are there substantial differences between the samples of houses reflected in the on site and the telephone surveys?

2. Are there any major discrepancies between the telephone survey and on site results, and if so, can they be explained?

Comparing the responses from homeowner who participated in both the telephone and on site surveys provides some insights into these questions. To investigate the first question, we used house size and RBES compliance rate as the critical comparison points. Based on the measured, on site data, the telephone survey homes were slightly larger than the sample as a whole and RBES compliance slightly higher, but these differences were not statistically significant.

Consistent with other similar studies, one area of discrepancy between the on site and telephone surveys was the homeowners' perception of appliance efficiency as compared to verified Energy Star appliances. Based on the overlapping group of survey respondents, it appears that many more homeowners identified their appliances as "energy efficient" than actually selected Energy Star models, and a few apparently failed to recognize that their Energy Star appliances were energy efficient.

Other areas of concern included the much higher penetration of furnaces and electric hot water found in the telephone survey as compared to the on sites, and variations in the distribution of space heating fuels. Correcting for errors in homeowners' responses based on the group of dual respondents indicates that the results of the two surveys are actually fairly consistent in these areas.

The final issue requiring further investigation was the incidence of manufactured homes. While the two surveys seemed to have similar results on the surface, comparison of the underlying responses raises the possibility that both surveys may have underestimated the incidence of manufactured homes.

9.2 HOUSE SIZE, PROGRAM PARTICIPATION AND RBES COMPLIANCE

House size, RBES compliance and program participant were three characteristics compared for the overlapping group of respondents to assess whether the homes included in the on site study were similar to the homes reflected in the telephone surveys. Analysis of the data suggests that the two surveys are quite similar on the basis of these three characteristics. The average house size of the homeowners who responded to both surveys was slightly larger than all on site survey participants (2,570 square feet for the overlapping participants as compared to 2,470 for the remaining on site houses).[1] The RBES compliance rate for the overlapping group was 61%, as compared to 58% for the on site survey at a whole. These differences are not statistically significant, which supports the conclusion that the on site survey is similar to the telephone survey with respect to house size and RBES compliance. The rate of self-reported participation in efficiency programs was virtually identical between the two groups at 32%.

However, the average self reported house size from the telephone survey was substantially different from the actual house size measured during the on site visit. The mean and median house sizes from the telephone survey are 2,175 and 2,000, respectively. The on site mean and median of 2,510 and 2,390 are in the range or 15 to 20% higher than the customer-reported areas. Since the on site visits include actual measurements of the homes, we concluded that the homeowner reports tend to be unreliable. To analyze this issue, we compared the house size as reported by the homeowner to the measured area from the on site for the 73 participants with data available from both sources. For smaller homes (under 2300 square feet), the homeowner reports were reasonably accurate on average. However, owners of larger houses (2300 square feet and up) tended to underestimate the size of their homes, sometimes by a large margin. For this segment of the sample, the average understatement was 640 square feet.

9.3 APPLIANCES

Phone survey participants were asked whether their appliances were “energy efficient” or “Energy Star” (if the respondent recognized the “Energy Star” designation). Through the on site visits, the auditors collected the make and model for the new appliances, and this information was used to verify the Energy Star models. There were 76 respondents who participated in both the phone and on site surveys.

As has been found in similar studies in other states, the phone responses indicate that most survey participants consider their appliances to be efficient. For refrigerators, about one-third of these respondents had Energy Star models, for clotheswashers, about two-thirds, and for

[1] This analysis was conducted using the measured area from the on site survey. This value was assumed to be more reliable than the customer-reported house sizes.

dishwashers about 40%. Also, 10% of responses regarding refrigerators and dishwashers indicated that the appliance was not efficient when it was an Energy Star model.

Table 9.1: Comparison of Appliance Responses

Phone Survey & On Site Overlap	Refrigerator	Clothes Washer	Dish-Washer
N [2]	49	29	42
Say "efficient" on phone	37	22	28
% say "efficient" on phone	76%	76%	67%
Verified Energy Star from on site	17	15	15
% verified Energy Star	35%	52%	36%
Both "efficient" and Energy Star	12	14	11
% both "efficient" & Energy Star	24%	48%	26%
% said “efficient” that are Energy Star	33%	63%	39%

9.4 SPACE HEATING FUELS AND SYSTEMS

The results of the on site and telephone surveys show some variation in the distribution of heating fuels and systems, as is shown in Table 9.1 below. One primary area of concern is that the telephone survey indicated about 70% of the homes had a hydronic system and 24% had forced air, as opposed to 82% and 14% from the site visits, respectively.

Table 9.2: Comparison of Heating Fuels and Systems

		Telephone Survey	On Site Survey
Heating Fuels			
	Oil	48%	42%
	Natural Gas	21%	19%
	Propane	20%	29%
	Other	11%	10%
Systems			
	Baseboard	51%	61%
	Radiant	19%	21%
	Forced Air	24%	14%
	Other	6%	4%

[2] N is the number of homes who responded to the questions regarding appliance efficiency on the phone survey, and had a new appliances and valid model number as verified by the on site visit.

We analyzed the 74 respondents of both surveys with complete heating system information to identify some of the potential issues.[3] This analysis uncovered some patterns of incorrect responses.

The telephone and on site surveys yielded the same responses for both the heating fuel and system type in 57 homes out of the 74 (77%). A number of homeowners were unable to distinguish between natural gas and propane, with most claiming to have natural gas when the fuel was actually propane (4 homes). The other major source of confusion regarding fuel type was identifying the primary heating system. Many homes had a wood stove as well as a fossil fuel central system, and some homeowners claimed to use wood as the primary fuel on the phone survey, but the on site visit results indicated that the fossil fuel system was the most commonly used (5 homes).[4]

Inconsistencies in categorizing the heating systems were identified in eleven homes (15%). The most frequent error was to claim a forced air system when the home had a hydronic system (4 homes), and three homeowners confused radiant and baseboard systems.

In the overlapping group of 74 homes with complete information, a total of ten homes were identified as having a forced air system in the telephone survey, as opposed to seven in the on site visits.[5] For this group of homes, the telephone survey overstated the penetration of force air systems by 30%. Applying this correction factor to the telephone survey as a whole, the adjusted proportion of homes with forced air systems would be 17%. This result is not statistically different from the 14% estimated from the on site survey.

9.5 WATER HEATING FUELS

The telephone survey results indicate that 25% of the homes had electric DHW, as compared to the 8% incidence documented in the on site survey. The homeowners' responses seem to be largely unreliable for this particular piece of information. Comparing the water heating fuels for the 76 respondents to both surveys indicates that 17 of these homeowners claimed to have electric DHW, but it was verified to be the case in only four homes in the on site survey. If this error were applied to the telephone survey as a whole, only 6% of the telephone survey would be estimated to have electric hot water.

9.6 MODULAR HOMES

5 MODULAR HOMES

[3] We were unable to ascertain the primary heating fuel and system for two homes in the overlapping group of 76.

[4] The primary fuel was identified from the site visits from the percentage of load estimated for each heating system and the amount of fuel used by each system. This information was typically provided by the homeowner.

[5] Four homes were incorrectly identified as having furnaces, and one home failed to be identified as having a furnace in the telephone survey, for a net difference of three.

Of the 158 homes in the on site survey, there were at least 23 modular homes and 4 double wide manufactured homes, accounting for 17% of the homes. This number compares favorably to the estimated 16% from the phone survey. When comparing the 76 homes with data from both the on site and telephone surveys, the overlapping data indicated there were 13 manufactured homes but only 9 (66%) were identified as such by the homeowner. If the error rate were consistent throughout the telephone survey, the penetration of manufactured homes would increase to 23%, which is the upper boundary of the confidence interval for the penetration of manufactured homes for the on site survey as a whole.

This result seems to indicate that the telephone survey may have underestimated the incidence of manufactured housing. However, it is possible that both the telephone and on site surveys exhibit the same bias for different reasons. In the on site survey, "manufactured home" was not a specific data point collected. These homes were identified reviewing from auditors' notes and builder information. It is possible that some modular homes were missed in this process. Since the homeowner responses were shown to be less than completely reliable, the 17% should be considered to be a lower boundary of the market share of residential new homes that are manufactured or modular housing.

10 FINDINGS AND RECOMMENDATIONS

This section presents the major findings from the survey and discusses recommendations for future efficiency efforts, policy implication and suggestions for the next evaluation in this market.

10.1 FINDINGS

The results of this study show some impressive gains in some common building practices. In comparison to the 1995 baseline study, heating system efficiencies have improved, the saturation of low E and argon windows has increased, and the most inefficient DHW systems (tankless coils) have virtually disappeared from new homes. The potential impact of these efficiency gains, however, is offset by some other significant trends. The pressure to build larger homes appears to be continuing, and the new homes in this sample, particularly the large homes, tend to have a much larger proportion of glazing than found in the previous study. Excessive oversizing of heating equipment is still a common practice.

While most homes are built at a midlevel of efficiency or higher, there are still a few homes being constructed with little regard to basic efficiency standards. About a quarter of the sample failed to come within 30% of the RBES compliance standard. In one-third of these homes, the high window glazing percentage was a contributing factor to the failure to meet code. Owner-built and manufactured homes account for more than half of this bottom stratum.

10.1.1 House Size

The new homes in the survey were large, averaging over 2,500 square feet with a 95% confidence interval of 2,284 to 2,545 square feet. The average home had over 800 square feet per occupant. A contributing factor to the considerable size of the living area was the prevalence of finished area in the basement.

The large, and sometimes excessive, house sizes have two major ramifications. First, and most obvious, is that larger homes use more energy, and this additional energy usage cannot be entirely offset by increasing the efficiency of the homes. The second implication is that the combination of large homes and few occupants makes it easier for these homes to meet the ASHRAE ventilation standards.

10.1.2 Code Compliance

While a solid majority of the homes (58% +/- 8%) passed the RBES code using the VTCheck software methodology or energy rating data where available, a low proportion (18%) had completed RBES certification forms in their homes. Compliance with the code appears to be much less of an issue than compliance with the certification requirements.[1] The major reasons for non-compliance with the code were the absence of foundation insulation and high ratios of glazing-to-wall-area. Conversely, higher code compliance has been achieved through an increase in the installation of basement insulation and an increase in heating system efficiency.

This rate of compliance, however, must be balanced against the reality of the standard building practices. Some homes that passed through the VTCheck methodology did not meet some basic efficiency standards, such as insulation levels of R-38 or higher in attic flats or R-30 in attic slopes. Also, the code does not cover some aspects of energy efficiency, such as air infiltration standards and heating system sizing.

10.1.3 Manufactured Housing

Manufactured housing accounts for a substantial part of the market, at least 17% +/- 6% at the 95% confidence level. Although this component of the housing stock is commonly produced to meet minimum code requirements when it leaves the factory, there is evidence to suggest that the thermal efficiency of these homes as installed on site is lower than site built homes. Only 11 of the 27 manufactured homes (42%) met the RBES compliance standard, as compared to 58% of the site built homes. Manufactured homes are much more likely to have electric DWH than the market as a whole, and also tended to have heating system equipment with lower efficiencies. In addition, these homes were not as tight as the site built homes. The BBRS study conducted by Xenergy for Massachusetts found that in modular homes the overhangs and center gap in the attic were frequently not sealed properly, which is consistent with the higher air infiltration rates found in manufactured homes in the current study.

10.1.4 Thermal Shell and Ventilation

Insulation and glazing characteristics were similar to the 1995 baseline study with about 65% of the homes (90% for walls) meeting or exceeding the minimum prescriptive RBES standard. The one exception was a significant increase in the number of homes with foundation insulation, from less than one half of the homes in 1995 having R-10 or more, to almost two-thirds of the homes meeting the minimum prescriptive RBES standard of R-10 in the current study. Other types of basement and foundation components, such as slabs, exposed floors and floors over unconditioned space, were underinsulated in most of the homes with these components.

Efficiency programs appear to be a major driver in promoting the mechanical ventilation in new homes. Whole house ventilation is required to meet the Vermont Star Home designation, and exhaust fans with timers are frequently recommended as a cost effective way to meet this standard. Participants in the utility or Vermont Star Homes programs were much more likely to

[1] It is possible that the RBES certification was submitted to the Vermont Department of Public Service or the town clerk for some homes, but certification through these mechanisms has been quite low.

install mechanical ventilation, including exhaust fans on timers (70% of homes as compared to 15% of the homes of nonparticipants).

Homes were tightly built, with two-thirds of the sample homes having a natural air changes per hour rate of .31 or less. Although the homes are tight, they generally meet the ASHRAE Standard 62 guidelines for air flow at the current occupancy levels.[2] Only 6% of the homes failed to meet the standard and did not have a whole house ventilation system. If the homes are assumed to be fully occupied at two people per bedroom, 44 of the 156, or 28%, fail to meet the ASHRAE criteria. In addition to the effectiveness of the efficiency programs in encouraging the installation of ventilation equipment, this result may also be an unintended consequence of the trend toward large homes.

For almost of the homes where both pressurization and depressurization tests were performed (as discussed above), these two tests produced different results, with the depressurization test higher in 39% (53) of the homes and lower in 56% (76). In a majority of the homes (63% or 85 homes), the cfm50 measurement made during the pressurization test was more than 10% different from the depressurization test, and in 17% (23 homes) the difference was 30% or more. The reasons for these differences are not readily apparent from the data collected in this study. These results indicate that averaging the two tests is likely to produce a more accurate assessment of air leakage than the depressurization test alone.

While window efficiency has been improving with a 10% increase in the percentage of homes with low E and low E/argon windows over the 1995 study, houses also have substantially more window area. In general, homes have a greater ratio of glazing to wall area than found in the 1995 study. The 1995 study showed that almost a quarter of the homes had less than .10 glazing in comparison to the wall area, and only 15% of the homes had more than a .15 glazing ratio. In the current study, this trend is reversed, with only 10% of the homes having a glazing to wall area ratio of less than .10 and 35% of the homes having more than .15 glazing.[3]

10.1.5 Heating and DHW Systems

Oil was the predominant fuel for both space and water heating, and saturation of low efficiency tankless coil water heating systems dropped precipitously from about 30% in the 1995 study to less than 5% in the current one. A large majority of the heating plants were in the mid to upper range of efficiencies. Most homes with boilers also had integrated water heating. The AFUE of the heating equipment were higher than found in the 1995 baseline study, and all systems met the minimum code requirement.

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[2] Standard 62 requires 15 cfm per person. Consequently, the level of occupancy of the house has an impact on the air flow requirements.

[3] The percentages for the 2002 study are based on the 139 homes with full site visits. There was not sufficient information to determine the percentage of glazing to wall area for the 19 homes where the shell data were obtained from the energy rating.

As is consistent with the 1995 baseline study, heating systems were consistently oversized to an excessive degree. The median oversizing was 81%, approaching twice as much heating output as required by the load. Only 7% of the homes had systems that were properly sized, as opposed to 40% with systems that are more than twice as large as needed. Excessive oversizing of the heating system results in a reduction in seasonal efficiency. These results are consistent with Xenergy's recent study of code compliance in Massachusetts.

10.1.6 Lighting and Appliances

The average number of fixtures per home increased markedly from the 1995 study, from 25 to 34. The penetration of CFL lighting among participants of the statewide or utility efficiency programs is high, in terms of the percentage of homes using this technology (80%), the number of CFL fixtures installed per home (50% of homes with four or more) and the incidence of installation in high use locations. This result indicates that the rebates for CFL fixtures and technical assistance provided by the efficiency programs have been effective at promoting these products.

Among survey respondents who did not participant in any efficiency programs, the penetration of CLF fixtures was much lower in all respects, leading to the conclusion that CFL fixtures have still not achieved acceptance in the general market.

The penetration of Energy Star appliances was reasonably high, with 47% of clothes washers, 36% of dishwashers and 27% of refrigerators meeting the Energy Star criteria at the time of purchase. Program impact on appliance purchase was mixed, possibly reflecting a lesser degree of promotion of Energy Star appliances through the program prior to 2001. Central air conditioning was found in 6% of homes, the same saturation rate as hot tubs.

Ceiling fans are a popular addition to new homes, with 103 homes (65%) of the sample containing at least one, and 43 of the 103 homes containing three or more. A total of 258 ceiling fans were installed in the 103 homes.

Approximately 33% of homes used either natural gas or propane to fuel their clothes dryers, a signficant increase from the 22% penetration of gas dryers found in the 1995 study.

10.1.7 Comparison of On Site and Telephone Responses

By comparing the overlapping group of respondents who participated in both the on site and the telephone surveys, we were able to assess the comparability of the homes reflected in the two studies and evaluate the telephone responses in a few key areas. The two surveys appear to be quite similar in regard to house size, RBES compliance and participation in efficiency programs. This comparison also uncovered a number of areas where homeowner telephone responses did not correspond well with the results of the on site survey. The largest discrepancy related to electric water heating. While the on site survey concluded that 8% of the homes had an electric water heater, the results of the telephone survey indicated 25%. Comparison of the overlapping group showed that the homeowners' responses were largely unreliable for this piece of information, with thirteen out of seventeen incorrect responses.

For a number of other house characteristics, the discrepancies between the telephone and on site survey responses were in the range of 15 to 30%. On average, the telephone responses underestimated house size by about 15 to 20%, with owners of smaller homes (under 2,300 square feet) providing reasonably accurate responses and owners of large homes (over 2,300) consistently underestimating the size of their homes. There tended to be some confusion among homeowners regarding the difference between primary and secondary heating systems and between natural gas and propane. Homeowners on average were more likely to state that they heat with a forced air system, although the auditor for the on site visit identified a hydronic system. When the responses from the overlapping group were corrected by the confirmed data from the on site visit, the distribution of house sizes, fuel types and heating system types for this subset corresponded well with the results of the on site survey as a whole.

As is consistent with the finding of similar studies in other states, many homeowners tended to identify their appliances as "energy efficient" although a smaller percentage purchased Energy Star models. While two-third to three-quarters of homeowners identified their appliances as "energy efficient," Energy Star appliances were verified in about one-third to one half of the homes.

The last data point compared was manufactured housing. Although both the telephone and on site survey results indicate that about 17% of the new homes were manufactured housing, it is possible that both surveys underestimated the penetration of this type of construction. In the overlapping group, homeowners underrepresented their homes as manufactured homes by about 30% on average. For the on site survey, "manufactured home" was not a specific data point on the survey form, and these homes were identified from auditors' notes and builder information, leaving the possibility that some manufactured homes could have been missed. Consequently, the 17% should be seen as a lower boundary of the penetration manufactured homes.

10.2 RECOMMENDATIONS

This section is divided into three parts: recommendations for future efficiency efforts in the residential new construction market, policy implications, and suggestions for the next round of evaluation efforts in this market.

10.2.1 Efficiency Potential

This study highlights a number of areas for potential efficiency improvements. The fact that 42% of the homes failed to meet the RBES standard, and about 30% failed by a substantial margin (more than 10%), emphasizes the importance of continuing to offer code support. Approximately half of the homes failing to meet the RBES standard by more than 10% were either owner-built or manufactured housing, indicating that efficiency efforts need to be designed to reach these groups. For manufactured housing, the components appear to meet the minimum code requirements when they leave the factory, leaving no leeway for problems occurring during the site construction. Efforts to improve the efficiency of manufactured housing should have a two pronged approach, with one set of initiative to encourage manufacturers to produce homes above the minimum standard and the second to promote efficiency building practices among the owners and builders who install the homes on site.

There are a few specific components of common construction practice that could be improved. With 73% of the homes built with 16" on center 2 x 6 wall construction, continuing program efforts to promote the use of 24" stud spacing in 2 x 6 walls, engineered corners and R-21 fiberglass would be warranted. This study also points to the need to continue to stress the importance of complete foundation insulation, including slab edges.

The excessive heating system oversizing shown to be common among the surveyed homes also presents opportunities for efficiency improvements. Recommended practice by ASHRAE standards is to oversize heating equipment by 25%. This study demonstrates that heating contractors seldom follow this recommendation. While the scarcity of small oil boilers on the market may have some impact on the contractors' decisions, it is also quite apparent that it does not explain the huge gap between correctly sized equipment and the typical heating systems installed in the surveyed homes. Efficiency efforts would have to be targeted to heating contractors and attempt to address the causes for the current practice.

Efficiency programs to date have been shown to be making solid progress in promoting efficient lighting and whole house ventilation using exhaust fans. Their track record on other energy star appliances appears to be more mixed. The next challenge is to influence the purchase and installation of these efficient products on a wider scale.

A final issue for consideration in program implementation is the few homes (4) in which the homeowners believed the homes had received energy ratings through the program, but in actuality had not. Program implementers need to find the balance between maintaining good relations with contractors and ensuring the integrity of their program.

10.2.2 Policy Implications

The trend toward larger homes with a higher percentage of glazing is likely to increase overall energy use to a far greater degree than can be offset by efficiency improvements. This pattern overshadows the overall goal of reducing energy usage, and cannot be effectively addressed through efficiency programs. While specific regulations to restrict house size are not likely to be feasible or desirable at this time, this trend should be considered in the context of state regulation and policies. One interesting finding of the survey was that Act 250 homes tended to be smaller than homes that were not subject to Act 250, although Act 250 does not have any specific size regulations. It is also entirely possible that a downturn in the economy will have an impact on the new construction market and the size and characteristics of new homes.

This study also points to a few area for potential code enhancements. While a majority of homes complied with the RBES code, there were still 42% that did not, and 30% that failed by a substantial margin. While these results may be considered to be reasonably good for a state with no code enforcement, they also indicate the need for continuing education and consideration of potential enforcement strategies. Program efforts to assist builders with RBES compliance may be providing critical services to this market segment. However, attempting to combine the efficiency program with enforcement may lead to deteriorating relationships with contractors. Since program success is highly dependent on developing and maintaining strong and positive relationships in the building community, coupling efficiency program efforts with enforcement strategies should be avoided.

Another result of this study indicates that the VTCheck software or prescriptive standards for insulation and heating equipment do not directly address some of the current lapses in building practices. Currently, the RBES code does not cover some relevant areas associated with the installation of insulation or heating system sizing. Also, the VTCheck software incorporates trade offs that allow homes to pass with substandard attic insulation. One approach would be to replace the VTCheck software with the prescriptive and performance-based standards. This approach would prevent homes from meeting the code standards with substandard insulation and be easier to administer, although fewer homes in the current study would have passed using this method.

This study also indicates that it should be possible to raise the minimum AFUE requirements for furnaces and boilers, and to increase the windows requirements to a minimum requirement of low E and argon. Since integrated DHW tanks have become the rule, an increase in the required efficiency of DHW could move along the elimination of the low efficiency tankless coils.

Vermont could also consider taking a similar approach to Massachusetts and strengthening the other code requirements, such as maximum sizes for heating equipment, improved installation standards for insulation and a minimum standard for DHW efficiencies above the federal minimum code requirement. If these elements are added to the RBES code, careful consideration should be given to tracking compliance and other enforcement strategies.

10.2.3 Recommendations for Future Evaluation Efforts

The approach of investigating the market from various perspectives, as proposed in the 1995 baseline study, was used to good advantage in the current round of evaluation activities. The combination of the telephone and builder surveys conducted by Xenergy and the on site survey results presented in this document yielded a more complex picture of the market place, and this approach should be employed again for the next round.

The primary area for potential adjustments may be in the objectives and implementation of the on site surveys. In this study, a major goal of the on site surveys was to determine RBES compliance by use of the VTCheck software. This approach required substantial time and effort in collecting the data for this task alone, leaving little possibility of investigating other issues. Since insulation levels seems to be reasonably consistent throughout the state, it may be possible to focus less on measuring each building component, and devote more time and effort to investigating other construction practices of interest.[4]

The comparison of the telephone survey responses to the on site verification may also be useful for refining the homeowner telephone survey. This comparison has highlighted specific areas where the homeowner telephone responses were more or less reliable, and can be used to focus the next telephone survey on the areas most likely to yield reliable results.

10.2.3.1 Approach to On Sites

We recommend revisiting the overall strategy for the next on site survey. Measuring and documenting the areas and characteristics of the attic, walls, windows and other building components for determining compliance through the VTCheck software composed a very large and time-consuming part of the site visits. The length of the site visits is restricted by the willingness of the participants, and cannot be longer than three hours on average. Even this length was a major hurdle for many potential participants. This decision to collect this detailed information limited the possibilities of investigating other issues.

While the documentation of code compliance via analysis of each building component was the major part of the site visit, the results were fairly predictable. Attic and wall insulation levels have been thoroughly documented and found to be reasonably consistent in both the current study and the 1995 baseline study. Windows also tend to meet the prescriptive RBES standard. Foundation insulation seems to be the one area where a significant improvement in building practices occurred between the 1995 and current studies.

Input from field staff and other sources point to areas beyond insulation levels where further investigation is warranted. These include point sources of indoor air pollutants such as garages and unvented appliances, DHW equipment and configuration, duct balancing and sealing, lighting levels and combustion safety. Comments from field staff are included in Appendix 2.

In the next round, one approach would be to record only the insulation levels and quality of installation, but not measure the areas. This single change would tremendously reduce the amount of time spent on this component of the site visits and open up the possibility of collecting data to evaluate lighting levels, indoor pollutants, wall construction details, etc. The insulation

[4] This issue was also raised in the recommendations from 1995 baseline study. However, given concerns regarding whether the 1995 baseline was representative of the market and the priority on assessing code compliance, the decision was made to stay with the time and labor intensive practice of measuring the building components for entry into the VTCheck software.

levels could be checked against the RBES prescriptive requirements to assess compliance levels, for homes without energy ratings. The down side of this approach would be that it would not be possible to calculate the design load for assessing heating system sizing, but this issue may not be significant since the practice excessive oversizing has now been thoroughly documented in both the 1995 and 2002 studies.

10.2.3.2 Questions for the Next Round

This study has illuminated some areas of building construction that should be further investigated in the next round. For the next study, we should consider adding the following questions.[5]

What is the actual penetration of manufactured homes among new homes?
Are manufactured homes less efficient than site built homes? If so, where is the potential for efficiency improvements?
Are homes overlit?
Is indoor air quality a problem in new homes?
Are there common issues with combustion safety?
Are heating and DHW systems correctly (and efficiently) configured and installed?
Are there common practices in the installation of insulation that effectively reduce the R-value?
What are common wall construction practices?
Are ducts properly balanced and sealed in homes with furnaces?
Are central A/C units properly sized?

Some of these issues were identified in the 1995 baseline study also, but as discussed above, the focus on measuring and recording areas for each building component limited our ability to address these issues.

Both the 1995 baseline and the current study indicate that heating systems are substantially oversized as a common building practice. This building practice is also common in Massachusetts, as shown in Xenergy's recent study of code compliance. The primary issue seems to be why this degree of oversizing is such a common practice and what strategies might be employed to try to correct the tendency toward excessive oversizing of equipment. These issues may be more appropriately addressed through the builder and heating contractor surveys in the next round.

[5] Many of these issues were highlighted by the subcontractors who performed the site visits. Their comments are included as Appendix 2.